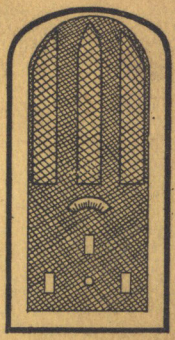

Servicing Superheterodynes

by

JOHN F. RIDER

published by
Radio Treatise Co., Inc.
1440 Broadway New York City

SERVICING SUPER-HETERODYNES

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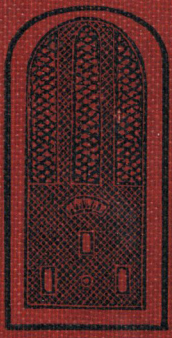

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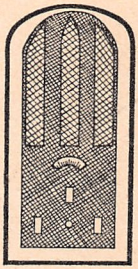

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AUTHOR'S NOTE

As far as we know there are no books devoted expressly to servicing of superheterodynes and it is hoped that this volume will clarify many of the problems encountered in such work.

We take this opportunity to tender full credit to all radio service manuals published by radio receiver manufacturers, and to express our thanks to the engineers, service managers and others responsible for the preparation of the literature and who have so kindly co-operated with the writer by furnishing him with whatever manuals and data were requested.

We wish to explain why we have devoted so much space to the subject of beats. Examination of many text books and courses of instruction show, that the subject does not receive extended discussion. Yet it represents the actual basis of the superheterodyne. The man who is familiar with beat or heterodyne phenomenon is familiar with the majority of the complaints accompanying the imperfect operation of a superhet in any fashion differing from the difficulties experienced in connection with tuned radio frequency receivers.

Much of the test data contained herein is the result of actual experience on the part of the author. We trust that the reader will find whatever practical information he requires and if any information is lacking, he will be sufficiently interested to communicate with the author.

The author alone read the proofs. If there are any errors in the text, every letter commenting upon such errors will be deeply appreciated.

INTRODUCTION

We shall not attempt to portray the historical background of the superheterodyne receiver. Let it suffice to say that its present day popularity does not mean that it is a new development. Superheterodynes were used during the World War and its development at that time may be said to have been due to the demand for a receiver which would afford more selectivity and greater sensitivity than was available with receivers of that time. There are certain names famous in connection with the superheterodyne receiver. Such names as Fessenden, Ferrie, Armstrong and Houck have appeared many times in radio literature. Peculiar as it may seem in the face of modern day developments the superheterodyne receiver of 1918 bears a very close resemblance to the superhet of 1931. Of course the similarity is that of basic operating principles and not actual control. An examination of radio literature ten or more years old shows perhaps three, four or even five separate controls as being necessary in order to secure the maximum efficiency and greatest stability from the superhet. Contrast this with the present day single tuning control circuits.

Perhaps you have wondered about the difference between the superhet and the conventional tuned radio frequency receiver. To express the actual difference, we must consider two items, the basic underlying principles and the passage of the received signal through the different parts of the radio receiver. Of course these two items are closely interlocked, inasmuch as the action

taking place during the passage of the signal through the superheterodyne receiver is the result of the circuit arrangement and the basic underlying principles. However, it is possible to differentiate between the two in the mode of expressing the actions.

The Difference Between The Superhet and The Tuned Radio Frequency Receiver

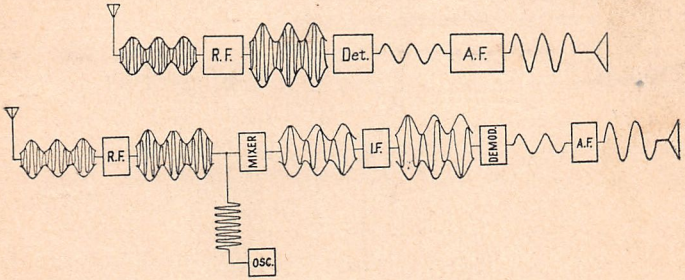
This explanation refers to the passage of the signal through the two systems. In the conventional TRF receiver, the modulated radio frequency signal transmitted from the broadcasting station is picked up by the aerial. This signal in its original form is amplified in the radio frequency amplifier to whatever degree of intensity is desired and it then is passed into the input circuit of the detector or demodulator tube. This tube separates the radio frequency carrier from the modulating audio frequencies. The significant item is that the detector tube is called upon to demodulate the original signal picked up by the aerial.

The same is *not* true in the superheterodyne receiver. The second detector or demodulator tube does not demodulate the original signal picked up by the aerial. The incoming broadcast signal carrying the modulating frequencies is combined with a locally generated signal in what is known as the 1st detector or mixer tube, tc produce a resultant signal. The resultant signal like the original signal retains the modulating frequencies, but differs from the original carrier frequency in its numerical value. The resultant (beat) signal is passed through a series of amplifiers and then is impressed across the input circuit of the second detector or demodulator tube where the modulating or audio frequencies are separated and passed into the audio frequency amplifier. A pictorial representation of the passage of the signal through

the two types of receivers is shown in figures 1 and 2. An examination of these two illustrations should help in this introductory explanation. A more thorough explanation follows.

The Advantages Offered By The Superheterodyne Receiver

At this stage one would be tempted to ask why such a complicated maze of actions has replaced the much simpler process to be found in the TRF receiver. Are any advantages offered by the superheterodyne receiver and if so, what are they? There are several advantages. First, is greater selectivity with the super. This is due to fact that selectivity is not determined solely by the tuned radio frequency part of the receiver or the



Figs. 1 and 2

input circuits of the receiver. The action of the frequency conversion and the design of the subsequent amplifiers is such that a difference of say 1 or 2 percent in frequency between a desired and an undesired station in the radio frequency section of the superhet is increased to perhaps 3 to 7 percent. Since most of the amplification takes place in the amplifier where frequency difference between the desired and undesired stations is greatest increased selectivity is obtained.

A second advantage is that increased sensitivity is possible with the superhet, assuming a constant number of tubes in both cases. This advantage is secured by virtue of the condition that low frequency circuits will allow greater amplification than high frequency circuits. As it happens the major amplification utilized in the superhet is secured at a frequency much lower than that encountered in the radio frequency amplifier of the TRF receiver. Third, is the actual realization of greater sensitivity for a certain number of tubes because the output signal is not determined solely by the intensity of the original input signal. Of course one must understand that a tuned radio frequency receiver can be made as sensitive as a superheterodyne, but in order to do so, more tubes are required and when tubes are added to a multi-stage tuned radio frequency amplifier, the probabilities of instability increase. Another advantage of the superheterodyne is that fewer continuously variable tuned circuits must be kept in track in order to provide the required selectivity and sensitivity. It is true that the number of tuned circuits to be found in a super will amount to as many, if not more, than may be found in a TRF receiver, but the difference is that fixed tuning is used in many of the circuits employed in the first named receiver. It should be understood that this brief reference does not complete the discussion of these subjects.

Section 1

THE PRINCIPLES UNDERLYING THE OPERATION OF THE SUPERHETERODYNE RECEIVER

The phenomenon of beats is the basis for the superheterodyne receiver. If you make an effort to understand this subject thoroughly, the operation of the complete receiver will become a simple matter. Clear comprehension of this subject will pave the way for remedying many apparently mysterious faults to be found in supposedly defective systems. A large number of complaints voiced about superhets involve some action related to beat notes, although the actual fault is not recognized. There are certain places where a beat note action is desired, but there are many places in the superheterodyne receiver where the beat phenomenon is not desired. Its presence causes the annoying and aggravating conditions. Many tuning conditions are productive of such difficulties and by stressing comprehension of the subject we feel that we are striking right at the root of the major complaints.

The Phenomenon of Beats

The production of a beat note in an electrical circuit is the result of the presence in the same circuit of two voltages or currents of different frequency. The production of the beat note in an electrical circuit is like that to be found in sound. However, since we are more concerned with electrical circuits, we shall devote the major

portion of this discussion of beats to electrical circuits.

Beat notes may be audible or inaudible, depending upon the frequencies involved. In order to recognize the presence of a beat note, certain provision must be made for that purpose. A beat note may exist in a circuit without manifesting its presence because suitable provision has not been made to indicate its presence. Then again a beat note may appear in a circuit although it is entirely unwanted and some defective condition enables manifestation of its presence.

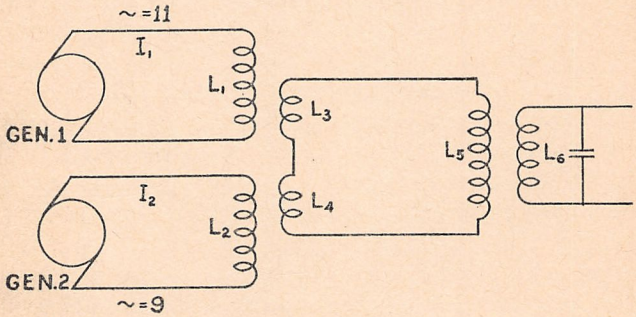


Fig. 3
Combining two voltages or currents of different frequency

Consider the two electrical generators shown in figure 3. Generator 1 (G-1) is generating current at a frequency of 11 cycles per second. Generator 2 (G-2) is generating current at a frequency of 9 cycles per second. An inductance is connected across each of these generators so that the voltage induced across L1 and L2 may be transferred to a neighboring circuit. Such a circuit contains L3 and L4 connected in series. The currents flowing through L1 and L2 induce voltages across L3 and L4. The combined voltage across this circuit is the result of the two voltages induced across L3 and L4 and its value is the algebraic sum of the voltage across L3 and the voltage across L4.

Suppose that we represent this condition in pictorial fashion. We shall assume that the intensity or amplitude of the individual voltages is the same. Accordingly we can illustrate the voltage across L3 as waveform curve A in figure 4 and the voltage across L4 as waveform curve B in figure 4. To determine the resultant voltage across the outside terminals of these two coils, we must combine the individual voltages. From what is taking place, we can say that the two voltages are mixed in this circuit and that the system is a mixer circuit.

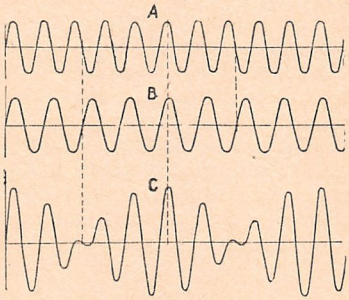


Fig. 4

Suppose that you examine curve A and B in figure 4. Curve A represents an 11 cycle wave and curve B, a 9 cycle wave. The vertical lines running through the curves represent time, in fractions of a second, starting from the extreme left. We take as the basis the 11 cycle wave. You will note that both curves start at zero and move in the same direction. They are in phase at the start. If you now examine the curves more closely you will note that after a few fractions of a second, about eight forty-fourths, the equivalent of two cycles of the 11 cycle wave, at the next fractional cycle, the 11 cycle wave is above the line and the 9 cycle wave is below the line and they reach their peaks in opposite directions with respect to the zero line, at almost the same instant. Moving in opposite directions they tend to neutralize each other. As they progress with respect to time, the difference in frequency creates a condition where at certain moments the two voltage waves move in the same direction, both being above the zero line or both being below the zero line. Such conditions

occur after about eleven forty-fourths of a second have elapsed, after twenty one forty-fourths of a second have elapsed, after about thirty one forty-fourths of a second have elapsed. As is evident we have a continually varying state of aiding and bucking of the two voltages. To determine the resultant voltage at any one instant, we ascertain the instantaneous value of each voltage and its direction, and then compute the value of voltage. The resultant is shown as curve C. If both voltages are above the zero line, the resultant voltage is above the zero line. If both voltages are below the zero line, the resultant voltage is below the zero line. In either case, the resultant voltage has an amplitude equal to the sum of the individual voltages. If both are below the zero line, the resultant voltage is equal to the sum of the voltages at that instant. If one voltage is at zero and the other has finite value in the positive direction, the resultant voltage is positive and equal to the value of the finite quantity. The same is true if one voltage is at zero and the other moves in the negative direction, that is, below the zero line, with the exception that the resultant voltage now has a finite value in the negative direction. The voltage at zero has no effect upon the other at that instant. If both voltages have finite values but move in opposite directions, the resultant voltage at that instant is equal to the smaller quantity subtracted from the greater and the direction of the voltage is governed by the direction of the greater voltage.

If you examine curve C very closely you will note that the amplitude variations of the resultant voltage appear with a definite periodicity. There appears a definite regularity in the process of aiding and bucking of the two individual voltages. In other words there appears a *cyclic* variation of the amplitude of the resultant voltage. This cyclic variation appears as curve D and is equal to the difference between the frequencies of the two original voltages generated by G-1 and G-2 and shown as curves A and B respectively.

The rate or periodicity in which the resultant voltage completes its cycle of amplitude variation is the *beat* frequency, in this case 2 cycles per second. If we arranged a circuit inductively coupled to L5 and made responsive to 2 cycles, a voltage at a frequency of 2 cycles per

second will be induced in coil L6. Starting with two frequencies, 11 cycles and 9 cycles respectively in L1 and L2, we produce a new frequency of 2 cycles in L6. Thus the mixer circuit is also a frequency changer.

Suppose for the sake of better comprehension that we consider several additional examples. Let us assume a voltage at 1500 cycles per second and a voltage at 700 cycles per second. If we feed these two frequencies into the L3-L4-L5 circuit, the two voltages will alternately aid and buck, add and substract. The resultant voltage will show amplitude variations at a rate equal to the difference between the two initial frequencies, namely 1500—700=800 times per second, producing a beat note of 800 cycles. If we assume a voltage at 95000 cycles and another at 176,000 cycles, the two voltages when passed into one circuit will combine (mix) and the resultant beat note will be equal to the difference between the two original frequencies namely 176,000—95,000=81,000 cycles. This means that if these two original frequencies are passed into the L3-L4-L5 circuit and another coil L6 made responsive to 81,000 cycles, is coupled to L5, a voltage at a frequency of 81,000 cycles will be available across its terminals. The same phenomenon will be true if the two original frequencies are 1,000,000 cycles and 834,000 cycles respectively, in which case the beat note is 1,000,000—834,000=166,000 cycles per second or 166 KC (kilocycles) per second. The same is true if the two original frequencies are 35,942,00 cycles and 12,470,000 cycles respectively, in which case the beat note is 35,942,000—12,470,000=23,472,000 cycles or 23,472 KC.

Whether or not a beat note is audible depends entirely upon its frequency and the method employed to make it audible. If the beat between the 1500 and the 700 cycle voltages is fed into L6 and a reproducing device is connected to this winding, an 800 cycle note or sound will be made audible. On the other hand if the beat note passed into L6 is that due to the presence of the 95,000 and the 176,000 cycle voltages, in which case the beat frequency is 81,000 cycles, the lack of response of the speaker to this frequency will render it inaudible to the ear. For that matter the ear is not responsive to any frequency approaching this value, so that if there

were a device which was capable of vibrating at this rate, the motion of the air particles it would set into vibration would remain beyond recognition by the ear.

Acoustical Beats

Digressing for a moment from electrical beats, let us consider acoustical beats or sound waves. Whatever is true with the electrical example is true in the case of sound waves. Beat notes are experienced when two audible sounds of different frequency are heard at one time. The two sound waves alternately interfere because of their phase relation and alternately re-enforce each other. The points of interference are the equivalents of the minimum resultant voltage, representing the sound intensity equal to the difference in amplitude of the two voltages. The points of re-enforcement are the equivalents of the sum of the amplitudes of the two voltages. As in the electrical circuit, the resultant sound wave reaches its peak or point of maximum re-enforcement at a definite rate, being equal to the difference between the frequencies of the two original sounds. Thus if we strike the note C^1 upon the piano, it gives forth a sound rated at 512 cycles per second. This may be classed as being the equivalent of a voltage rated at 512 cycles.

If we now strike E^1 upon the piano it gives forth a sound of 640 cycles per second. This may be said to be the equivalent of generating a voltage of 640 cycles. Striking C^1 and E^1 simultaneously is the equivalent of feeding two voltages into the mixer circuit. The resultant sound striking the ear of the listener is the resultant voltage. Accompanying this sound will be heard an alternating strengthed and weakened sound with a periodicity equal to 640—512=128 cycles. The rate at which the sound reaches its greatest strength is the same

rate at which the resultant voltage reaches its peak value per second. The beat frequency or beat note is the same in both cases.

It might be an interesting experiment to listen to the beat note produced by two automobile motors running at slightly different speeds. The beat is very easily discernible. The piano note experiment may also be tried. If two tuning forks of slightly different pitch are available, they can be struck to produce a beat.

The Phenomenon of Electrical Beats When One Frequency Is Modulated

The use of sine waves as shown in figure 4 to illustrate the production of a beat note is quite satisfactory for that purpose, but it is not a true representation of exactly what takes place in a superheterodyne receiver.

The item requiring consideration is the modulation of the original broadcast carrier. The presence of a modulated wave at A in figure 3 instead of the sine wave does not change the action taking place but it does change the exact appearance of the resultant beat frequency wave.

The beat note produced in the superheterodyne receiver is due to the mixing of the modulated broadcast carrier with a locally generated signal. The latter is produced by a special tube (oscillator) utilized for that purpose. These two signal waves are fed into a mixer circuit (a tube in this case, which will be considered separately later in this text) and the action taking place is similar to that experienced with the two sine waves. However the presence of modulation in one of the waves results in the presence of modulating frequencies in the resultant beat note. To illustrate the resultant beat note in its exact manner is beyond the scope of this book. What we shall do is to offer an elementary concept of the appearance of this wave in order to expedite comprehension. Viewed from the technical angle, the wave-

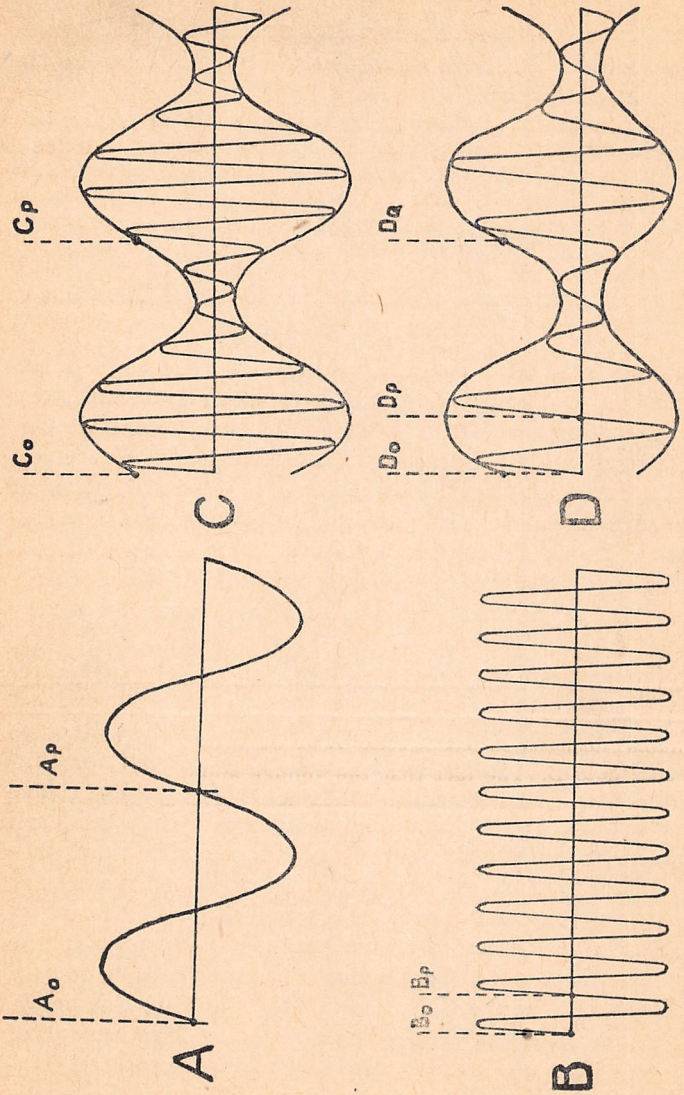


Fig. 5

form shown is not correct, since it is more complex, but as an illustration of the presence of the modulation envelope upon the beat note, it will suffice.

Consider curve A in figure 5. This can be assumed to be a 1000 cycle tone produced by a tuning fork. Curve B is the 1,000,000 cycle carrier wave produced at the broadcasting station. When the modulating signal is superimposed upon the carrier wave, the resulting wave resembles that shown in curve C. Now the distance between Ao and Ap represents one audio cycle or one one-thousandth part of a second. The distance between Bo and Bp represents one RF cycle of the carrier or one one-millionth part of a second. When the carrier is modulated and appears as shown, the wave envelope resembles the original 1000 cycle sine wave and the time required for one audio cycle still remains one-thousandth of one second. The fine lines within the envelope represent the carrier wave cycles.

If we now mix the modulated wave with a sine wave of say 760,000 cycles we produce a beat note as previously described which has a frequency of 1,000,000—760,000 = 240,000 cycles per second. The cyclic variation of the resultant voltage is the difference between the two frequencies or the time required for one cycle between Do and Dp is one two-hundred-forty-thousandth of a second. See curve D. But if you examine the waveform shown at D, you note that the peak values vary in accordance with the 1000 cycle tone, the time required for one complete cycle of the envelope being one-thousandth of one second. The original modulating frequency present in the modulated 1,000,000 cycles carrier C is present in the 240,000 cycle beat note D. The fact that the voltage amplitudes are not the same both sides of the zero line for curve D is due to an action within the mixer tube of the receiver.

If we break down curve C, it consists of the carrier and the modulating frequency. In turn if we break down curve D it consists of the 240,000 cycle wave and the modulating frequency of 1000 cycles. As in the case of the modulated carrier, the beat frequency is also a modulated carrier wave. In other words the mixing has resulted in the generation of a so called new carrier wave, in the form of the beat note of 240,000 cycles which is modulated at 1,000 cycles. As is evident there has been a conversion of carrier frequencies, in this case a reduction from 1,000,000 cycles to 240,000 cycles with the original modulation characteristics.

If we imagine that this modulated wave of 240,000 cycles circulates through the winding L5 in figure 3, it is possible to couple L6 to L5 and have a transfer of the voltage from the L5 to the L6 circuit. If desired, the modulated beat note can be demodulated and the 1000 cycle component separated from the 240,000 cycle carrier. This is done in the superheterodyne receiver. How it is done is the function of another section of this book.

If the superhet input circuit is tuned to a 1,000,000 cycle carrier modulated at 1000 cycles and the receiver is so arranged as to produce a beating frequency of 760,000 cycles, the modulated carrier passed into the demodulator tube in order to secure the original 1000 cycle note for amplification in the audio amplifier is of 240,000 cycles or 240 KC. (kilocycles).

The carrier and modulation frequencies selected are purely illustrative. The carrier can be of any value and the modulating frequency can be of any value. By the same token beat frequency may be of any value. The fact that it is modulated does not enter into the production of the beat frequency. The presence of modulating frequencies is of importance in another direction but not with respect to the beating process. Thus we can reduce a 550 KC carrier wave to 100 KC by beating it with a 450 KC locally generated wave or a 1400 KC carrier to 175 KC by beating it with a 1225 KC locally generated wave.

Now, the value of the beat frequency is equal to the difference between the two frequencies which are mixed. Accordingly the beating frequency may be *higher* or *lower* than the original carrier frequency. Referring to the previously mentioned examples 550 KC—450 KC= 100 KC. However, if the beating frequency is 650 KC instead of 450 KC, the resultant beat frequency will still be 100 KC. The optimum relation between the carrier and the oscillator (beating) frequencies will be discussed at greater length in another section. At this time it is necessary to enter upon a brief discussion of another subject in order to allow continued discussion

of beat frequencies with respect to certain phenomena encountered in superheterodyne receivers.

Harmonic Generation and Their Presence In Receivers

Before continuing further with the phenomenon of beats it is necessary to consider the generation of harmonics because their presence in a superheterodyne receiver is productive of much trouble in the form of sounds (whistles) originating from supposedly mysterious sources. In order to enable a remedy some knowledge of harmonic generation is required. In this connection we again repeat that when two electric currents or voltages of differing frequency are present in the same circuit, a beat note will be produced. Bear this in mind for future reference in this section.

The vacuum tube used in all radio receivers for the purpose of amplification, detection, etc. has a peculiar operating characteristic. We take for granted that under certain operating conditions, the output of the tube is a faithfully amplified reproduction of the input. However under other conditions, the aforementioned is not true. The operating characteristic of the tube is such that the output circuit has in it frequencies other than those present in the input circuit. These frequencies bear a definite numerical relation to the frequencies present in the input. The output frequencies include the original or fundamental frequency applied to the input and certain multiples or harmonics of the fundamental. The exact intensity of the various harmonics with respect to the fundamental is a variable depending upon the design of the circuit, the operating voltages applied to the tubes, etc.

The relation between the fundamental and the harmonic frequencies is such that the harmonic is at all times of a higher frequency than the fundamental. Thus, harmonics may be 2,3,4,5,6,7,8,9, etc. times the funda-

mental frequency, irrespective of the numerical value of the fundamental. The fundamental may be of any frequency, say between 30 and 10,000,000 cycles and have present in the output circuit, harmonics of the 2nd, 3rd, 4th, 5th, 6th, 7th, etc. order. Since operation of the superheterodyne receiver involves frequencies between 130 and 1500 KC, it might be well for future use, to tabulate some of the harmonics of the fundamentals within this range. Consideration up to the 5th harmonic should be sufficient. All values in KC.

Frequency	2nd	3rd	4th	5th
125 KC	250 KC	375 KC	500 KC	625 KC
126	252	378	504	630
127	254	381	508	635
128	256	384	512	640
129	258	387	516	645
130	260	390	520	650
131	262	393	524	655
132	264	396	528	660
133	266	399	532	665
134	268	402	536	670
135	270	405	540	675
170	340	510	680	850
171	342	513	684	855
172	344	516	688	860
173	346	519	692	865
174	348	522	696	870
175	350	525	700	875
176	352	528	704	880
177	354	531	708	885
178	356	534	712	890
179	358	537	716	895
180	360	540	720	900
200	400	600	800	1000
220	440	660	880	1100
240	480	720	960	1200

Frequency	2nd	3rd	4th	5th
260 KC	520 KC	780 KC	1040 KC	1300 KC
261	522	783	1044	1305
262	524	786	1048	1310
263	526	789	1052	1315
264	528	792	1056	1320
265	530	795	1060	1325
280	560	840	1120	1400
320	640	960	1280	1600
350	700	1050	1400	1750
400	800	1200	1600	2000
450	900	1350	1800	2250
500	1000	1500	2000	2500
550	1100	1650	2200	2750
600	1200	1800	2400	3000
650	1300	1950	2600	3250
700	1400	2100	2800	3500
750	1500	2250	3000	3750
800	1600	2400	3200	4000
850	1700	2550	3400	4250
900	1800	2700	3600	4500
950	1900	2850	3800	4750
1000	2000	3000	4000	5000
1100	2200	3300	4400	5500
1200	2400	3600	4800	6000
1300	2600	3900	5200	6500
1400	2800	4200	5600	7000
1500	3000	4500	6000	7500

In order that we have exact figures for reference later in this text, we have tabulated the harmonics of frequencies slightly higher and lower than the exact intermediate frequencies used in existing superheterodyne receivers. With this table as the basis we can consider the phenomena related to beat notes and harmonics. Although we have made the statement that the intensity of harmonics was not a factor, it might be well to

mention that as a rule, the higher the harmonic, the less its intensity. However it is necessary to remember that what we may call a weak harmonic may be of sufficient intensity to become audible in a modern receiver. The high degree of sensitivity present with the modern receiver makes possible definite utilization of even the weakest harmonics as signals of calibrated frequency. Examples of this will follow in a subsequent paragraph.

Having made the statement that the output circuit of a tube may have harmonics of the input frequency, reference to the table of harmonics gives one an idea of the numerical values of these harmonics. Now, you should not glean the impression that the reference made to harmonics in the output circuit of a tube means that you have troublesome harmonics in the output circuit of every tube. Such is not the case and the general run of amplifier tubes when used as such should be dismissed from your mind. However bear in mind that tubes functioning as detectors in a certain fashion and oscillators as a whole are prolific sources of harmonic frequencies. The table shown indicates the numerical value of harmonics up to the 5th, of certain fundamental frequencies. Harmonics of other frequencies may be computed by simply multiplying the fundamental by whatever order of harmonic is desired. Thus the 7th harmonic of 175 KC is 175 x 7 or 1225 KC. The 8th harmonic is 175 x 8 or 1400 KC. etc.

Now, each of these harmonics is a signal, be it weak or strong and must be considered as such. Many examples of service procedure upon superheterodyne receivers involve the use of a harmonic of a fundamental frequency as the test signal. As an example, consider the popular intermediate frequency of 175 kilocycles. Depending upon its method of application this frequency can be the fundamental for alignment of the inter-

mediate frequency amplifier and may also be used for the adjustment or alignment of the RF and oscillator circuits by utilizing its harmonics and tuning the circuits to be aligned to the proper frequencies. Reference to the harmonic table shows that the 4th harmonic of 175 KC falls in the broadcast band, being 700 kilocycles. Thus adjustment of an RF or oscillator circuit at 700 kilocycles is possible. By utilizing the higher harmonics, say, 5th, 6th, 7th and 8th, adjustment of an RF circuit at 875, 1050, 1225 and 1400 kilocycles is possible. A similar condition exists for all intermediate frequencies, as is evident upon the table. For an intermediate frequency of 260 kilocycles, adjustment of RF or other higher frequency circuits is possible at 780, 1040, 1300 kilocycles, these being the 3rd, 4th and 5th harmonics. Just how these harmonics are used will be dealt with in greater detail during the discussion of RF and IF trimmer condenser alignment. Mention of such operation at this time is made solely to show that the harmonics may be utilized as test signals and that despite the low intensity in comparison with the fundamental, it still is of sufficient magnitude to justify due consideration.

Examination of the harmonic table shows a list of harmonics of the broadcast frequencies above 1000 KC. These values become of importance during the use of short wave convertors and adaptors. Although we do not list fundamentals above 1500 KC, you must realize that such harmonic action is to be found with the higher fundamental frequencies.

Recognizing that a harmonic is a signal of a certain frequency, it is easy to understand how a beat note may be produced between a fundamental frequency and a harmonic of some other fundamental. Consider an 850 KC fundamental as for example the carrier of a broadcasting station operating upon this frequency. Then imagine

an oscillator erroneously adjusted to 171 KC instead of 175 KC. The 5th harmonic of this frequency adjustment is 855 KC. If the 850 KC carrier and the 5th harmonic of the 171 KC are fed into the same circuit, a beat note equal to 855,000—850,000 or 5,000 cycles will result. It is also possible, although the phenomenon does not occur frequently where two harmonics beat against each other and produce a beat note.

The action possible between a fundamental and a harmonic of another frequency gives rise to trouble in many superheterodyne receivers. Such troubles are in the form of whistles which are constantly present as background noises or during the process of tuning. As a rule the trouble is associated with a defective condition in the receiver. Recognition of its possible reasons cannot help but be of aid during the efforts to remedy the fault. Consider the following. The receiver is tuned to a 1040 KC signal. The intermediate frequency in the receiver is 262 KC. In order to produce this intermediate frequency, the beating signal must be 1040 KC + 262 KC or 1302 KC. Now, the beat note produced has its own harmonics. Examination of the table of harmonics shows that the 4th harmonic of 262 KC is 1048 KC. If by some error or defect, the carrier and the beat frequency get into the same circuit, let us say into the input circuit of the 2nd detector or demodulator tube, the 4th harmonic of the IF signal will beat against the broadcast carrier and produce an 8000 cycle whistle which will be a background for the regular signal. A condition such as this is possible if the antenna lead is adjacent or coupled to some inductance in the 2nd detector (demodulator) grid or plate circuit, particularly to the RF choke in the plate circuit.

A phenomenon associated with beat circuits is that of ZERO BEAT. This condition exists when the two frequencies which have been mixed are of like value. The result is that no beat note is produced.

Heterodyning, Its Causes and Effects

The term heterodyne is synonomous with the phenomenon of beats. A heterodyne note is a beat note. Beating one signal against another to produce a third

is the same as heterodyning one signal with another. Thus when a beat note is produced between two signals of different frequency, a heterodyning action exists. This word is used in connection with whistling sounds experienced with many receivers. The presence of two broadcast carriers of slightly different frequency in the same circuit results in the production of a heterodyne (beatnote) whistle. Thus whatever efforts are made to eliminate undesired beat notes are also eliminating the heterodyne note.

There are times when heterodyne phenomena experienced is of such nature as to be very confusing. Any condition in a radio frequency amplifier which will alter the operating characteristic of the tube so that it has departed from true action as an amplifier may result in the production of a heterodyne whistle during certain dial adjustments. During the process of tuning the frequencies present in the RF tube acting like an oscillator will beat against other broadcast signals and produce an audible beat in the form of a whistle.

There are times when a radio frequency tube which is being overloaded will tend to cause a heterodyne note with some other broadcast signal which because of excessive power or perhaps imperfect selectivity has found its way into the circuit. Consider a radio frequency amplifier tube which is being overloaded. The plate circuit of this tube will contain harmonics of the input frequency. Let us say that the signal being received is of 610 kilocycles. The 2nd harmonic of this signal is 1220 kilocycles. If another broadcast carrier rated at approximately 1220 KC finds its way into the overloaded tube circuit, a beat note is possible between the approximate 1220 KC carrier and the 2nd harmonic of the original 610 KC signal. If both carriers are absolutely accurate upon their allocated waves as stated, the beat note will be zero, but any slight variation during opera-

tion of the transmitters will cause a heterodyne whistle. It is evident that tuning and operating of the amplifier tubes has much to do with whether or not an annoying heterodyne whistle will be produced. The sensitivity of a receiver has some effect in as much as response to two weak signals of slightly different frequency will result in heterodyning, where one carrier beats against the other and produces the beat note. No adjustment of the receiver will alleviate this trouble unless the difference in signal intensity between the two carriers is sufficient to enable the reduction of receiver intensity to the point where it responds to but one of the signals and the heterodyne whistle is reduced to a negligible minimum.

Heterodyne whistles or squeals are apt to occur because of the presence of parasitic oscillations in the oscillating system of the receiver. Certain conditions related to the operating voltages applied to the oscillator in the superheterodyne receiver will give rise to such parasitic oscillations. (The remedy will be given later). These parasitic oscillations will produce beats with other frequencies present in the receiver.

A condition of heterodyning of peculiar type must be mentioned at this time. It is possible for two broadcast carriers of widely separate frequency to find their way into the RF amplifier and be present in the output. If two broadcast carriers separated by a frequency difference equal to the intermediate frequency find their way into the 1st detector or mixer input circuit, the heterodyne note produced will pass into the intermediate frequency amplifier and both signals may be present in the output. An example of this is the presence of an 860 KC carrier and 600 KC carrier. These two beat and produce a heterodyne signal of 260 KC. If the intermediate frequency amplifier is peaked at 260 KC, the heterodyne signal will get through to the demodula-

tor tube (2nd detector) and be heard through the speaker. Of course such a condition can occur only if the receiver is tuned to one of these frequencies and the other by virtue of power or location with respect to the receiver, gets into the circuit.

Another example of heterodyning, wherein is involved another term, "image frequency" is as follows: A beat note of correct frequency can be produced if the beating frequency is lower or higher than carrier frequency. As a rule the beating frequency is higher than the carrier by the value of the required beat note. If it so happens that another signal of such frequency that when acted upon by the beating frequency will produce the required beat gets into the circuit, it too will pass into the intermediate frequency amplifier and will be heard in the speaker. An example is the following. The required beat note is 175 KC. The desired carrier signal is of 650 KC. In order to produce the desired beat of 175 KC, the oscillator in the receiver is adjusted to 650 + 175 or 825 KC. Now the sum of 825 and 175 is 1000 KC, which means that if a signal of 1000 KC gets into the circuit when the 650 KC signal is being received, the oscillator adjustment of 825 KC will result in the required beat of 175 KC and both signals will pass through the receiver. In this case the 1000 KC signal is the "image frequency". By the same token the 650 KC signal is the image frequency if the desired signal is 1000 KC. and the oscillator is tuned to 825 KC. However, tuning the oscillator below the carrier is seldom encountered in practice.

Another version of this example is that to be experienced when the oscillator in the receiver is adjusted to the sum of the broadcast carrier and the intermediate frequency, in this case 1000 + 175 or 1175 KC. If a 1350 KC signal gets into the circuit during the reception of the 1000 KC signal, the beat produced between the 1350 KC carrier and the oscillator signal of 1175 KC, will be 175 KC and will pass through the intermediate amplifier and through the balance of the system. In this case the 1350 KC signal is the "image frequency".

Elimination of the image frequency is a matter of selectivity obtained in the radio frequency amplifier. To eliminate the image frequency, particularly when the receiver is located in close proximity to several broadcasting stations, it is imperative that a high order of selectivity be available in the radio frequency amplifier.

Section 2

EXPLANATION OF THE DIFFERENT TYPES OF SUPERHETERODYNE CIRCUITS

Before attempting to discuss the various types of superheterodyne circuits it might be well in order to obviate repetition, to mention those parts of the receiver which are common to the different types. Certain sections of the different types of superheterodynes are similar if not identical. Such sections are the audio frequency amplifier, the power pack and the speaker. Their function is identical to that found in any other type of receiver. Of course all audio frequency amplifiers are not alike. Certain new systems have come into use, one of great prominence, namely the Loftin-White and direct coupling. These systems cannot be tested in the normal fashion and require special instructions. Discussion of these systems is not required in this section because of the breakdown analysis of the superhet in Section 3. As to power packs and speakers, there is nothing special to be said about the units employed in superheterodyne receivers. The data furnished about such units in the Perpetual Trouble Shooter's Manual, written by the author of these lines is applicable to the fullest extent. As to speakers the same applies.

Under the circumstances, reference to various types of superheterodyne circuits will mean those parts of the receivers which are different with respect to circuit design, function, etc. in the different receivers.

The Standard or Conventional Superheterodyne Receiver

It is difficult to establish the definition of standard or conventional. Perhaps the best explanation is that which is generally understood to exist when casual reference is made. Such a system consists of certain components. These are:

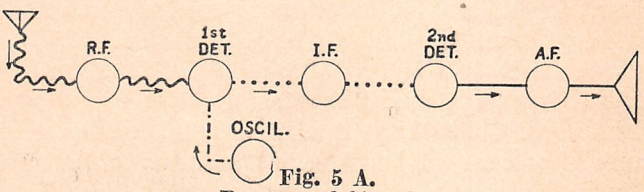


Fig. 5 A.
Passage of Signal Currents through Standard Superhet

1. The RF amplifier or selector circuit.
2. The 1st detector, mixer, frequency changer or whatever other term is applied to this tube.
3. The oscillator employed to generate the local oscillations.
4. The intermediate frequency amplifier.
5. The 2nd detector or demodulator tube.
6. The audio frequency amplifier.
7. The speaker.
8. The power pack.

Neglecting the current flow due to the operating voltages the sequence of tube operation and the paths of the various signals currents are shown in figure 5A. This is the primary circuit. Starting with the aerial, the modulated radio frequency carrier is indicated by the wavy line. It goes into the radio frequency amplifier or pre-selector circuit. From there it continues into the 1st detector or mixer. Into this tube is fed the output of the oscillator indicated by the dot-dash line. This current is the "beating" or "heterodyning" signal. The two combine in the mixer tube to produce the new modulated carrier, the intermediate frequency signal indicated by the dotted line. This signal passes into the intermediate frequency amplifiers, the IF tubes. After amplification the signal is fed into the 2nd detector or demodulator tube. The output of this tube is the audio frequency signal current indicated by the solid line. After suitable amplification in the audio frequency tubes, the current is fed to the speaker.

The use of a single circle to indicate a section of the receiver does not mean to convey the thought that but one tube is used in each of these sections. There are certain parts of the receiver which utilize but one tube, but there are also other sections, where several tubes are used depending upon the exact design of the receiver. The fact that several are used does not mean deviation from the standard or conventional design. This deviation is a matter related to the function of the tubes and certain circuit constants.

Finding it difficult to establish a definition for what is standard or conventional we must make use of that which is implied by common practice. One possible definition of a standard or conventional superheterodyne is that system which employs a separate tube for mixing purposes, a separate tube for generating the beating or heterodyning signal (oscillator), a separate tube or tubes as intermediate frequency amplifiers, a separate tube as a demodulator and a separate tube or tubes as the case may be for audio frequency amplifiers.

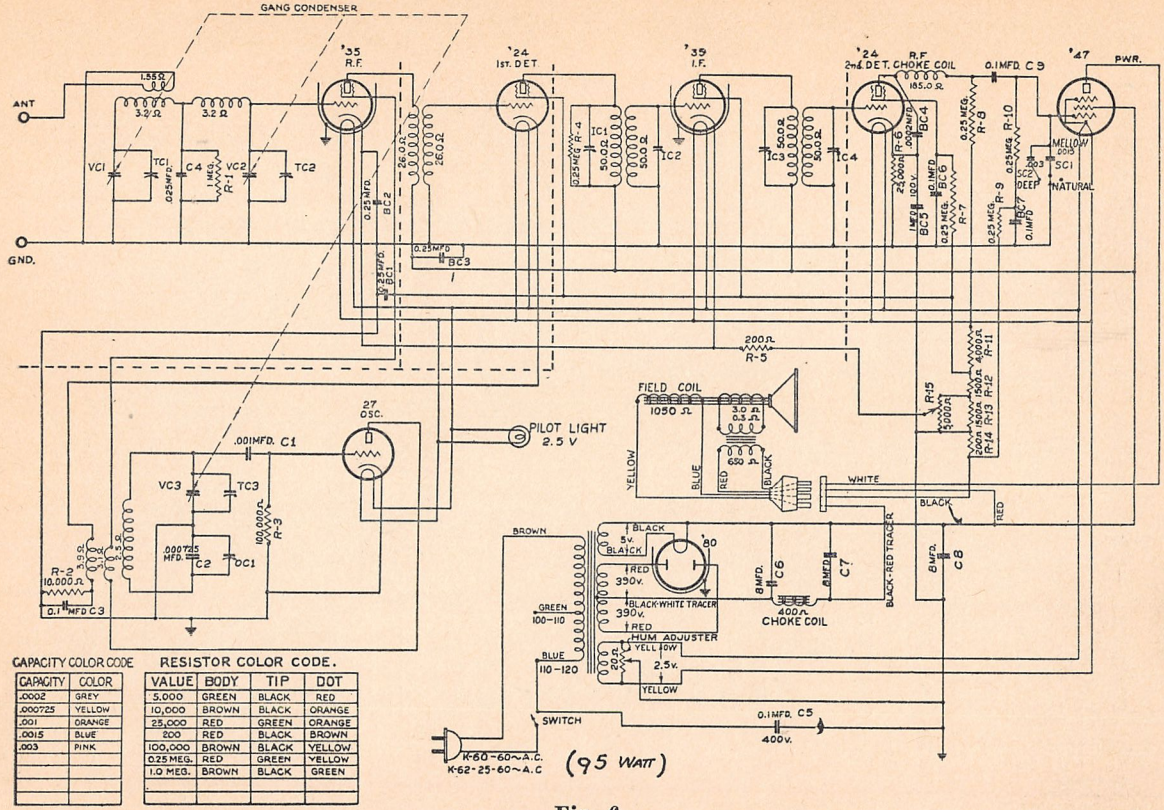
The number of tuned circuits or the number of tuning controls have no bearing whatsoever upon whether the circuit is standard or otherwise. A standard type superheterodyne may have one, two or three tuning controls. This depends entirely upon the design and the ideas of the design engineer. This statement is made in order to clarify the problem, should it ever arise, relative to the possible difference between a modern single tuning control superhet of the standard variety and a supposed standard type superhet several years old, wherein two or possibly three tuning controls are used. The difference is purely a matter of whether or not the oscillator tuning is available as a separate control to supplement the regular radio frequency amplifier tuning control. In the modern super these two sections of the receiver are linked to a common control as a matter of convenience

to the operator. In this connection, such unified control has helped eliminate many complaints relative to double point tuning, because correct tracking of the oscillator and the radio frequency tuning condensers enables reception of a station at but one point along the periphery of the dial, that is, providing the system is in perfect condition. An example of a modern superhet of the standard circuit variety relative to the basic principles is shown in figure 6.

The Autodyne Type of Superhet

The autodyne type of superheterodyne is not commonly used, although it was used to a great extent in years past. (See "Second Harmonic" system). The primary difference between this and the standard superheterodyne is found in the use of a single tube as a combined 1st detector (mixer) and oscillator. Obviously this single tube is doing the work of two separate tubes used in the standard type of superhet. This is made possible by the fact that a vacuum tube can be utilized as a combination oscillator and detector. The principle of utilizing a tube in this fashion is not new, having been used for many years in connection with continuous wave reception in amateur radio ranks and in the second harmonic superhet.

The exact principle of operation will be described during the discussion of mixer tubes in the next section. In the meantime, let it suffice to say that the combination detector and oscillator is connected to the radio frequency amplifier in normal fashion and the beat note required for the intermediate frequency amplifier is obtained by tuning the input of the autodyne tube to a frequency which differs from the received modulated broadcast carrier by the intermediate frequency. (This is not true in the "Second Harmonic" system). The



CAPACITY COLOR CODE

CAPACITY	COLOR
.0002	GREY
.000725	YELLOW
.001	ORANGE
.0015	BLUE
.003	PINK

RESISTOR COLOR CODE.

VALUE	BODY	TIP	DOT
5,000	GREEN	BLACK	RED
10,000	BROWN	BLACK	ORANGE
25,000	RED	GREEN	ORANGE
200	RED	BLACK	BROWN
100,000	BROWN	BLACK	YELLOW
0.25 MEG.	RED	GREEN	YELLOW
1.0 MEG.	BROWN	BLACK	GREEN

Fig. 6
An example of a standard circuit superheterodyne
(Courtesy Kolster Radio)

broadcast carrier and local oscillator currents are flowing in the same circuit. They combine to produce the beat note in the plate circuit of the tube. This beat note or heterodyne current is then passed into the intermediate frequency amplifier in normal fashion. (See Section 3, Mixer and IF amplifier classifications.)

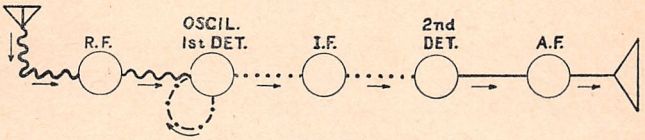


Fig. 7
Passage of Signal Currents through Autodyne type of Superhet

Current flow in the autodyne receiver may be represented as in figure 7. The legend for the current is wavy line—RF; dot-dash line—Oscillator; dotted line—IF and solid line is AF. A circuit illustration of this system is shown in figure 8. This circuit is elementary and does

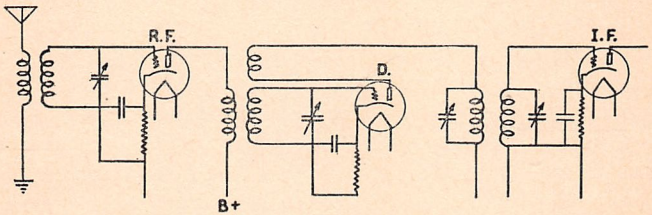


Fig. 8
Autodyne System

not include all of the units present, but will suffice to show the use of a regenerative detector which is adjusted so that it is continually oscillating over the entire wave band. The tuning condenser of the mixer circuit "D" is made to track with the tuning condenser

of the RF circuit (RF tube) and to differ in frequency adjustment by the value of the IF frequency fed into the IF tube. If the combination mixer and oscillator tube ceases oscillating, the circuit no longer functions as a superheterodyne.

Adaptors

The use of the tuned radio frequency receiver designed for broadcast work as a short wave receiver means the use of a separate short wave tuning circuit, which may consist of RF amplifiers and a detector. The radio frequency and detector tuning circuits are resonated to whatever short wave band is desired. A plug is arranged in the short wave receiver output circuit so that it may be plugged into the receiver detector socket, of course, after the regular detector tube has been removed. The short wave signal tuned in on the short wave receiver is fed into the audio amplifier for further amplification. A simple short wave adapter circuit, wherein the operating voltages are secured from the broadcast receiver power supply is shown in figure 9. The tuner is of the regenerative detector type. The connections to the various tube elements terminate in a five prong plug. Since the control grid of the short wave detector is used, and since the detector in the receiver is not used, the control grid lead and terminal of the plug are not used. The heater voltage is secured by means of the H leads and the heater contacts upon the plug. The cathode of the regenerative short wave detector joins the K terminal of the detector socket used in the receiver. When this plug is inserted into the detector socket in the receiver, assuming that a transformer coupled audio system is employed, the circuit appears as shown in figure 10. The dotted lines show the contacts between the plug and the socket. The plate

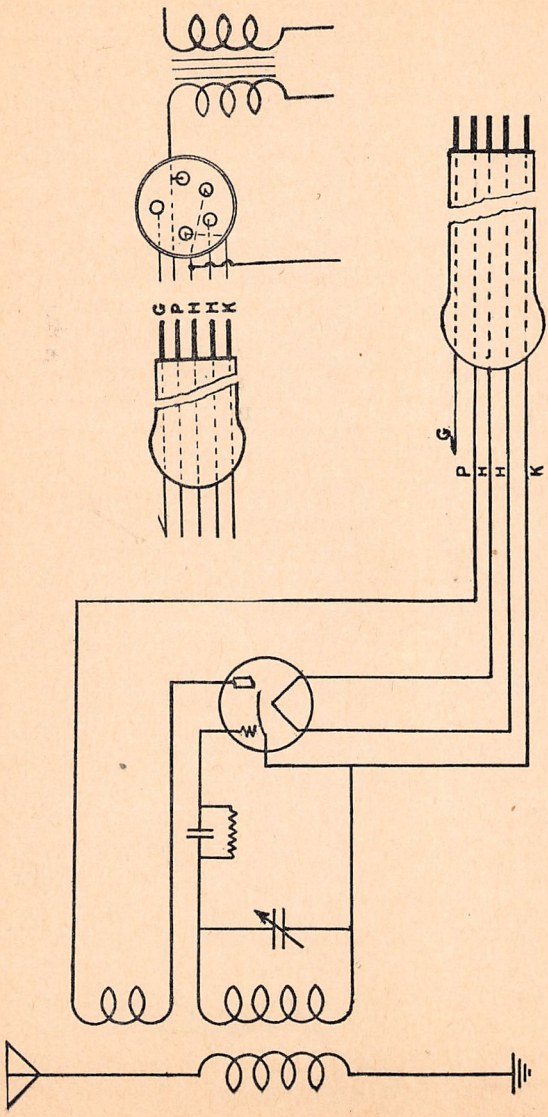


Fig. 9
Short Wave Adaptor
Fig. 10 (upper)
Connection of plug and detector socket

voltage for the regenerative short wave detector is secured through the primary of the audio transformer, through plate contact of the detector socket in the receiver, through the plateprong of the plug, through the tickler coil of the regenerative detector to the plate of the regenerative short wave tube. This type of system is the simplest and does not require any further discussion.

The use of the tuned radio frequency receiver as a superheterodyne is another matter. Here we find that the convertor becomes a superheterodyne unit, in as much as the function of the complete convertor or adaptor is to produce the equivalent of the beat note in the conventional superhet. This type of receiver may be compared with the standard superheterodyne, wherein the mixer and oscillator tubes are not a physical part of the complete receiver. However two differences must be noted. The first is, that the mixer tube, the oscillator and the radio frequency amplifier stage if used, are tuned to the short wave frequencies rather than to the broadcast band as in the case of the conventional system. The other difference is that the tuned radio frequency amplifier part of the broadcast receiver becomes the intermediate amplifier and tuning of the intermediate amplifier is accomplished by tuning the radio frequency amplifier to some specified frequency, usually above the normal broadcast band. The beat note produced by the superhet short wave convertor is that required by the tuning adjustment of the tuned radio frequency amplifier within the receiver. As an example of the above consider the following: The broadcast receiver has a wave band of 1500 to 540 kilocycles. The short wave band to be received extends from 4000 to 3000 kilocycles (75 to 100 meters). The short wave RF system if one is used is tuned to the desired frequency within this band. The mixer circuit is likewise tuned

to this frequency. The oscillator in the superhet short wave converter system is tuned to some frequency, which when mixed with the frequency of the short wave broadcast carrier will produce the beat for the intermediate frequency amplifier. Suppose that the short wave carrier is 3800 KC. The intermediate frequency decided upon is 560 KC. The adjustment of the oscillator then is 3800 + 560 or 4360 KC. The intermediate frequency amplifier is the tuned radio frequency system in the broadcast receiver and in order to function at 560 KC the tuning is adjusted to that frequency

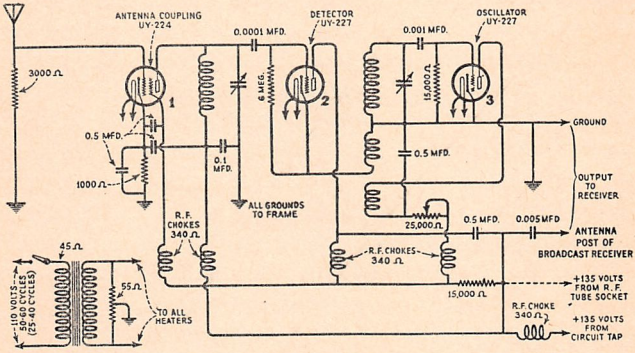


Fig. 11
RCA Superhet Short Wave Convertor
(Courtesy RCA—Victor Co.)

and remains at that adjustment during the operation of the superhet convertor. The output of the superhet convertor is the 560 beat note, modulated at whatever modulation frequencies are present in the original short wave broadcast carrier. This is fed into the broadcast receiver by one of several methods, usually through the aerial and ground posts of the receiver.

An example of such a system as used in a commercial receiver is shown in figure 11. This wiring diagram shows the RCA Radiola Short Wave Adaptor. An ex-

amination of this circuit shows three tubes in use. The first tube, functioning as a radio frequency amplifier is the antenna coupling tube. A tube is used as the detector or mixer and another tube is used as the oscillator. Recognizing the use of individual tubes for the last two functions, this system when utilized with a radio receiver of the tuned radio frequency type becomes a superheterodyne of standard design. As is evident in the wiring diagram, the output of the mixer tube is fed to the aerial post of the receiver. This is the same as feeding the output of the regular mixer in a standard type superheterodyne into the intermediate frequency amplifier. The method of feeding the signal from the oscillator into the mixer tube is through the winding in the cathode circuit of the detector. Various types of coupling between the oscillator and mixer are in use. For a more complete description see Section 3, Mixer classification. The plate and screen voltages required for the adaptor tubes are secured from either a tap upon the voltage divider in the receiver or from whatever RF tube socket in the receiver supplies 135 volts. The heater voltage for the various tubes is secured from a separate transformer. Contrast this system with that shown in figures 9 and 10 where the heater voltage is secured from the power transformer in the receiver power pack.

Another commercial example of a superhet short wave converter is the Stewart Warner, model R 301 A, B and E. This is shown in figure 12. In this case the aerial is fed directly into the short wave detector or mixer tube. The beating signal is secured from the oscillator, a separate tube and is fed into the detector by means of a coil in the cathode circuit of the detector. This coil is coupled to the oscillating circuits of the oscillator tube. The output of the detector is fed into the aerial terminal of the broadcast receiver. The plate supply for

the superhet converter tubes is secured from the broadcast receiver. The heater current for the superhet convertor tubes is secured from a separate transformer.

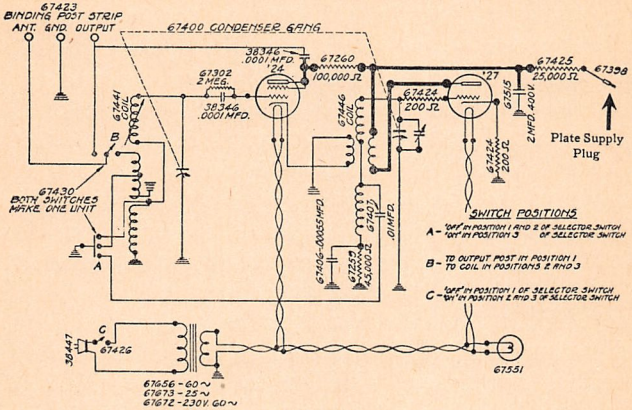

67423
BINDING POST STRIP
ANT. GND. OUTPUT
67400 CONDENSER GANG
38346 .0001 MFD.
67260 100,000 Ω
67425 25,000 Ω
67396
67302 2 MEG.
38346 .0001 MFD.
67441 400Ω
67446 400Ω
67424 200 Ω
67424 200 Ω
67515 2 MFD. 400 V.
Plate Supply Plug
67430 BOTH SWITCHES MAKE ONE UNIT
SWITCH POSITIONS
A - "OFF" IN POSITION 1 AND 2 OF SELECTOR SWITCH "ON" IN POSITION 3 OF SELECTOR SWITCH
B - TO OUTPUT POST IN POSITION 1 TO COIL IN POSITIONS 2 AND 3
C - "OFF" IN POSITION 1 OF SELECTOR SWITCH "ON" IN POSITION 2 AND 3 OF SELECTOR SWITCH
67506 - .00035 MFD.
67220 43,000 Ω
67407
.01 MFD.
38447
67426
67656 - 60 ~
67673 - 25 ~
67672 - 230 V. 60 ~
67551

Fig. 12
Stewart Warner Superhet Short Wave Convertor
(Courtesy Stewart Warner Radio)

The sequence of the signal currents through such a converter is very similar to the autodyne superhet shown for the receivers mentioned thus far.

The autodyne type of superheterodyne short wave converter is very similar to the autodyne superhet shown in figure 7. If we imagine the use of a radio frequency amplifier tube as the antenna coupler tube, the oscillating detector shown in figure 7 can be imagined to be the combination mixer and oscillator of the autodyne type of superhet converter. While it is possible to arrange the system so that the operating voltages are secured from the receiver, the usual method is to employ separate filament and plate voltage supply sources. Up to the present writing the autodyne type of converter as a separate unit to be used with a commercial receiver has not been manufactured upon a commercial

scale. Various kits are available but no units have been made by the prominent receiver manufacturers.

No doubt the man who has followed this discussion of the superheterodyne has been wondering about the possibilities of insufficient selectivity and sensitivity with the autodyne system. Actually the autodyne system (except the second harmonic circuit) does result in a loss of selectivity and sensitivity. This is true in both the complete superheterodyne and in the converted superhet where the autodyne type of mixer-oscillator is used. This is due to the fact that the oscillating circuit wherein is also flowing the incoming carrier current is not tuned exactly to resonance with the carrier frequency. However, this is not as bad as it seems, in as much as sufficient amplification is available in the intermediate frequency amplifier to compensate for this loss and sufficient selectivity is also available in the intermediate system to allow the required choice between stations without interference.

Short Wave Conversion With Two Oscillators

This method of operation entails the use of a complete broadcast range superheterodyne and the use of a separate short wave detector with plug-in or tapped coils so as to afford a number of frequency bands or wave length ranges. The short wave detector is connected to the aerial and made responsive to whatever short wave signal is desired. A special oscillator operating at a frequency which when combined with the frequency of the short wave carrier will produce a beat lying within the broadcast band is a part of the converter system. This beat is fed into the input circuit of the broadcast receiver, which has been tuned to the proper frequency. Since this signal is the equivalent of a regular broadcast signal, it passes through the super-

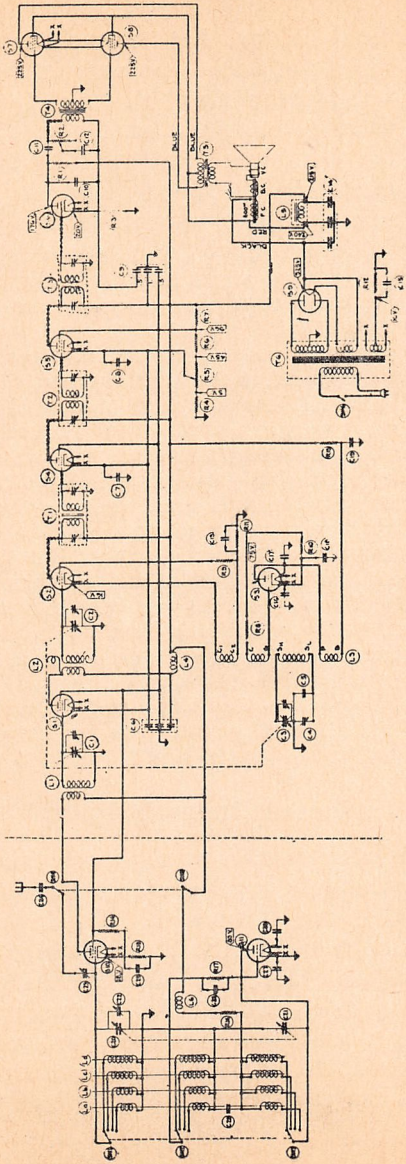


Fig. 7 A

het in conventional fashion. Let us consider an example. The complete circuit of such a receiver is shown in figure 7A. The units shown to the left of the dash line are the short wave detector and oscillator. The units to the right of the dash line constitute the conventional broadcast superheterodyne. The switches associated with the inductances in the short wave detector and oscillator circuits control the tuning of the respective circuits.

Suppose that the desired signal is 3700 kilocycles. Suppose further that the adjustment of the radio frequency part of the regular receiver is to be 650 KC when the receiver is operated in conjunction with this short wave superhet converter. This means that the adjustment of the short wave oscillator will be 3700 + 650 or 4350 KC. As a matter of fact because of the tracking of the short wave superhet detector and oscillator tuning condensers, this beat frequency difference is maintained at all times. Continuing further, the beat note of 650 KC is fed into the receiver. This signal now is acted upon by the regular oscillator in the broadcast receiver so as to produce the required beat for the intermediate frequency signal. The IF frequency is 175 KC so that the adjustment of the receiver oscillator is 825 KC. The 175 KC intermediate is produced, passed through the IF amplifier, is demodulated by the 2nd detector and is made audible through the speaker. Thus starting with a 3700 KC signal we pass through two beat frequencies of 650 and 175 KC in order to produce the modulation frequencies present in the 3700 KC signal. At the same time two separate beating frequencies are employed, namely 4350 KC and 825 KC.

The Second Harmonic System

This system of operation was popular several years ago and was the sole type of superheterodyne manufactured by RCA and Brunswick. The development of the system was due to Houck. We made mention earlier in this section that this type of superhet differs from the conventional or standard. The difference is twofold. First, a single tube is used as a combination mixer and oscillator. Second, the intermediate frequency is not the beat note between the incoming carrier and the locally

generated signal. Instead, the heterodyne signal which is fed into the intermediate frequency amplifier, is that which is produced by beating the incoming carrier with the second harmonic of the signal produced by the dual acting oscillator and mixer tube. An example of this is the following. Consider the circuit in figure 13.

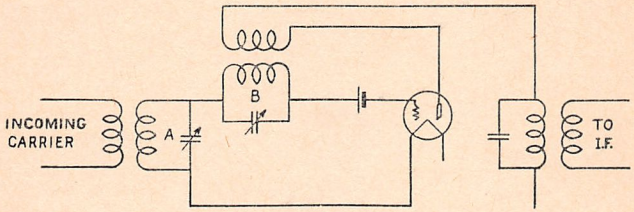


Fig. 13
Second Harmonic Circuit

This diagram shows the schematic of the combination mixer and oscillator. The usual deficiencies of such a combination circuit have been avoided by a very ingenious method. Circuit A is tuned to the incoming broadcast signal carrier frequency. Let us say that this is 1,000 kilocycles. Let us further assume that the intermediate frequency is 50 KC. The beating signal required to produce the desired intermediate therefore, is 1,000—50 or 950 KC. Since this quantity is the second harmonic of the oscillator frequency, it stands to reason that the oscillating circuit must act at half this frequency or 425 KC. This is circuit B in figure 13. The inductance and capacity of this circuit are so arranged that the fundamental frequency is 425 KC. The second harmonic of this frequency is 950 KC. The beat note produced is 50 KC and the beating action takes place upon the second harmonic. A comparison of this type of autodyne circuit with that previously mentioned

shows how it is possible by virtue of the presence of circuit A, to secure maximum sensitivity and selectivity in the mixer circuit. This condition is easily realized if we recognize the fact that accurate tuning to the incoming carrier is available.

Section 3

BREAKDOWN OF THE SUPERHETERODYNE RECEIVER AND INDIVIDUAL FUNCTION OF PARTS

Having completed the elementary discussion of what we believe to be the most important part of superheterodyne operation, we are ready for the discussion of the individual parts of this very popular receiver.

An item of importance from the angle of servicing is to remember that the information furnished about any one part of a superheterodyne receiver is applicable irrespective of the type of superhet in question, providing of course that the part being discussed is found in the receiver. Fortunately, because of general utility, certain statements pertaining to operation, defects, symptoms and trouble shooting of the respective parts are universally applicable.

The RF Amplifier

The function of the radio frequency amplifier in the superheterodyne receiver does not differ very greatly from that used in the TRF receiver. However, in contrast with the multi-stage systems in tuned radio frequency receivers, the average superheterodyne does not employ more than one stage. This is true in the majority of midget receivers. In some console models two radio frequency amplifying stages may be found. Under the circumstances one cannot help but wonder how it is

possible to provide the required selectivity and sensitivity with but one or two radio frequency amplifiers. The reasons are twofold. In the first place, the selectivity factor offered by the radio frequency amplifier is not the sole controlling influence as far as the total selectivity available with the receiver is concerned. As previously stated a definite gain in selectivity control is offered because of the conversion of the carrier frequencies. This phenomena when supplemented by accurate resonating of the intermediate frequency transformers enables an increased order of selectivity. Let us see how.

Imagine that the radio frequency amplifier is tuned to resonance with a 1000 KC station. (Whatever will follow is applicable at other frequencies and the choice of 1000 KC is purely for the purpose of illustration.) Let us further assume that a nearby station is operating upon 1010 kilocycles, a frequency difference of 1 percent. Now, the design of the average radio frequency amplifying stage, even the finest, is such that total separation of two stations operating in such close frequency proximity and each with reasonable power is well nigh impossible. To secure the required selectivity, several stages are employed. The single stage radio frequency amplifier in the superhet is beset with similar difficulties. The fact that it is used in a superhet does not alter its inherent characteristics. The fact that proper selectivity is secured is due to what will now be described.

If we decide that the intermediate peak frequency is 260 kilocycles, the heterodyning frequency is 1260 KC. If both stations are heterodyned, the undesired station will still be 10 KC away from the peak frequency. However the frequency difference in the intermediate frequency amplifier no longer is 1 percent; it now is slightly more than 3.8 percent. With a multi stage accurately tuned intermediate frequency amplifier or with a single stage accurately tuned intermediate frequency

amplifier wherein at least two transformers with four tuned circuits are used, this frequency difference is sufficiently great to furnish the required amount of selectivity. A possible method of picturizing this condition is shown in figure 14. The solid line marked carrier represents the original carrier frequency of 2000 KC. and also the newly produced carrier (IF signal) of 260 KC. The solid line "A" upon the 1 percent ordinate illustrates the frequency separation in the radio frequency amplifier when the 1010 KC signal is also present in the circuit.

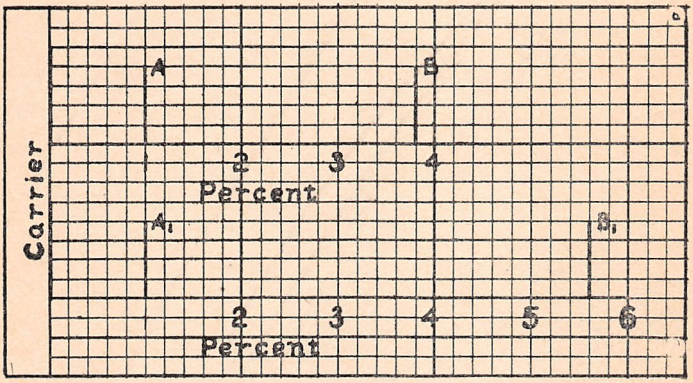


Fig. 14
Graphic representation of selectivity variation in RF and IF systems

The solid line B shows the frequency separation on a similar percentage basis between the 260 KC carrier and the undesired station which has also been heterodyned but is 10 kilocycles away. If we imagine the intermediate frequency to be 175 kilocycles instead of 260 KC the frequency difference is as indicated by the dashed lines, where A1 is the equivalent of A and B1 is the equivalent of B. The increased gain in selectivity as the intermediate frequency is decreased is obvious.

The elimination of "image frequency" is a more important role of the radio frequency amplifier in the superheterodyne. Reference to Section 1, "Heterodyning, Its Causes and Effects" explains the significance of the "image frequency". From what is said in the two paragraphs devoted to that subject it is evident that the

radio frequency part of the receiver functions at all times to prevent the presence of two broadcast carriers which are separated by a frequency difference equal to twice the intermediate frequency. The presence of two such signals will result in two signals being heard in the output.

Careful attention to the relation between the value of the intermediate frequency with respect to "adjacent channel" selectivity (this term means the separation of stations 10 kilocycles apart) and elimination of the image frequency due to the action of the radio frequency amplifier shows the opposite advantages of the intermediate peak with respect to the radio frequency system. As is obvious, the higher the intermediate, the less the advantage as far as "adjacent channel" selectivity is concerned, but the greater the advantage as far as "image frequency" elimination is concerned. Thus it evolves upon the intermediate frequency amplifier to provide the channel selectivity and upon the radio frequency amplifier to provide elimination of the image frequency. (See "The IF Amplifier" in this section for further details about the frequency of the intermediate frequency amplifier).

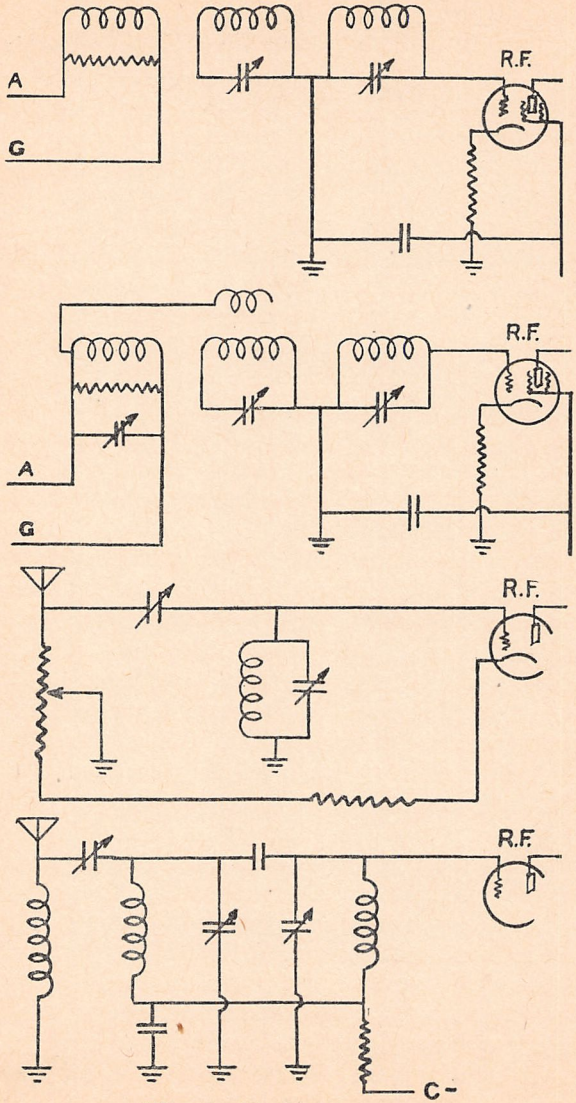
Another paramount function of the radio frequency amplifier is to minimize the presence of two stations which are separated by a frequency difference equal to the peak adjustment of the intermediate frequency amplifier. Although this subject was mentioned in connection with "Heterodyning" in Section 1 repetition will not be amiss. The adjustment of the radio frequency amplifier particularly if it is of the multituned type must be accurate to one frequency, unless special circuits are used. An example of this will be given in this section. (See "Double Spot Circuit".) Any deviation from accurate resonance, particularly upon the high frequency end of the scale is apt to result in the

presence of two signal currents of the frequency difference mentioned, in which case heterodyning in the detector circuit will take place and an interfering signal will be heard.

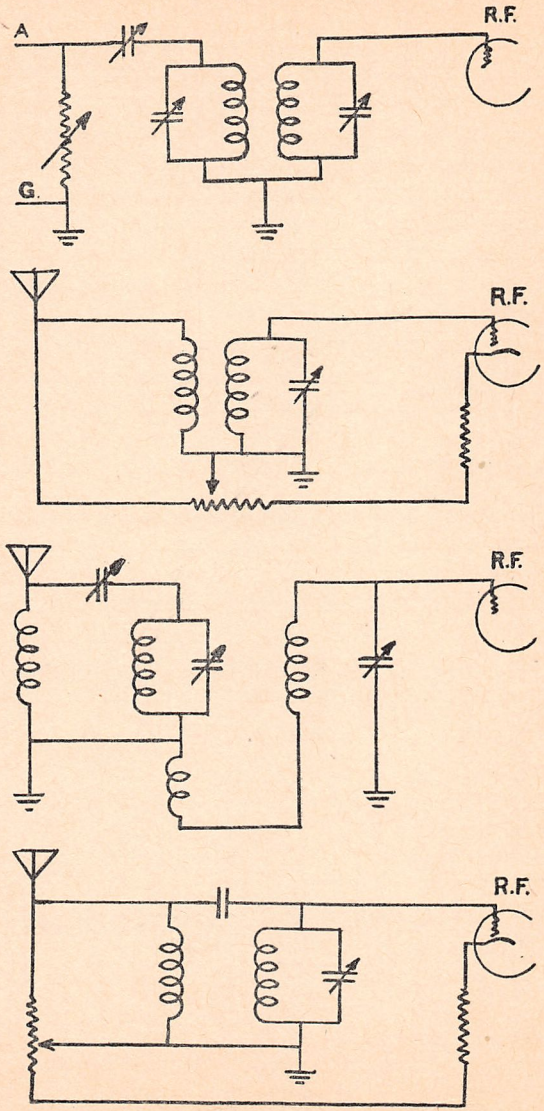
Still another important consideration is the elimination of cross modulation in the radio frequency amplifier tube. Such a condition results from the presence of an exceptionally strong and a weak signal in the radio frequency amplifier. Thus the radio frequency amplifier must limit the intensity of undesired signals and also contain some volume limiting device whereby the signal input is definitely under control. The importance of this consideration has been minimized of late by the development of the variable mu tube, but it deserves note because of the receivers sold prior to the sale of the variable mu tube. The problem of tube replacement is considered elsewhere in this text. (See Section 8)

Although the examples cited so far in this section have been of the broadcast frequency variety, whatever has been said is equally applicable to short wave systems. Fortunately, the wider separation of the frequencies allocated to short wave broadcasting stations prevents the occurence of the troubles cited thus far. However there are many subjects of note in connection with short wave reception and they shall receive individual attention.

The types of radio frequency amplifier circuits and transformers used in superheterodyne receivers differ in but small measure from those employed in modern tuned radio frequency receivers. Several examples of such circuits are shown in figures 15, 16, 17, 18, 19, 20, 21 and 22. In each case, these circuits are used in existing commercial superheterodyne circuits. As a matter of fact these eight systems constitute a summary of the types of circuits in modern use. While it is true that the illustrations show the system being used between the aerial



Figures 15, 16, 17 and 18
Examples of RF circuits



Figs. 19, 20, 21 and 22
RF system and volume circuits

and the 1st RF or the only RF amplifier tube, cases exist where these circuits are used as RF transformers between the aerial and the 1st detector or mixer tube. The radio tube has been omitted in such receivers and the aerial feeds directly into the first detector through one of these systems. Then again cases exist where a combination of these circuits are employed in various ways. Thus a single tuned RF transformer is used between the aerial and the RF tube and a double or triple tuned circuit is used between the RF and the mixer tube. In some instances the sequence of transformers is the reverse of that just stated. In each and every case the objective is a high order of selectivity.

The Double Spot Circuit in The Atwater Kent Receivers

A special effort to eliminate the image frequency is found in some of the Atwater Kent superheterodynes. Special mention is made in this section and full instructional details covering the adjustment of this circuit will be found in Section 6. Particular reference is made to this circuit because its adjustment entails specific details concerning the type of RF oscillator re-

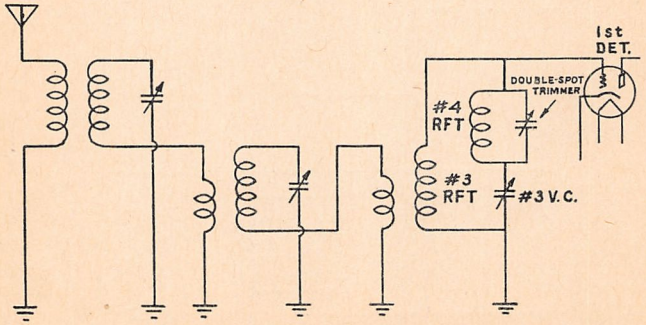


Fig. 23
Double Spot System in Atwater-Kent "H" Series Superhets

quired and the adjustment of the signal output of this oscillator.

The circuit used is shown in figure 23. An example of its application is the H (72) series of superheterodynes shown upon pages 114-M to 114-R in the Perpetual Trouble Shooter's Manual. The units used in the double spot tuning circuit as it is known, are the No. 3 RF transformer, the No. 4 RF transformer, the No. 3 variable condenser and the double spot trimmer connected across the No. 4 RF transformer. The actions of the respective parts of this circuit are not difficult to comprehend. All of the tuned circuits ahead of the secondary of No. 3 RF transformer are used to provide a high order of selectivity of the carrier frequency desired. The combination of No. 3 and No. 4 RF transformers and the two associated condensers constitute a double tuned circuit, that is, a circuit simultaneously tuned to two frequencies. The complete circuit is tuned to the frequency desired and the circuit consisting of No. 4 RF transformer and the double spot trimmer are tuned to the image frequency. The function of the double spot tuned circuit (No. 4 RF transformer and the double spot trimmer) is to short circuit all currents of the image frequency. To accomplish this the circuit is tuned to 260 kilocycles higher than the frequency adjustment of the pre-selector circuit. The reason for selecting the 260 KC adjustment is due to the use of a 130 KC peak in the intermediates of this receiver. Although we have shown the development of the image frequency, an example of the application of this circuit will not be amiss. Suppose that the desired carrier is of 1240 KC. The intermediate frequency being 130 KC. requires an oscillator adjustment of 1370 KC. (The reason for always utilizing a beating frequency *higher* than the desired carrier is discussed under the heading "The Oscillator" in this section.) The beating frequency will produce a beat of 130 KC if there is present in the pre-selector circuit a carrier of 1500 KC. To eliminate the possibility of any such carrier finding its way into the first detector circuit, the double spot tuning circuit is adjusted to 1500 KC and by virtue of its position in the system it effectively short circuits the system at this frequency. As has been previously mentioned, the image frequency is always *higher than the desired carrier frequency by twice the numerical value of the intermediate frequency.* To eliminate the image frequency, the double spot circuit is so tuned and tracked with the pre-selector condensers that it is *always 260 KC higher than the*

desired carrier frequency, irrespective of the frequency setting of the remainder of the pre-selector system.

Neutralized Radio Frequency Amplifiers

Although it is not common practice in modern installations, quite a few of the older superheterodynes employed two or three tuned radio frequency stages of the conventional type and some of these stages were neutralized. Special discussion of these systems is not required in as much as the process of neutralization is of the conventional type.

Regenerative Radio Frequency Amplifiers

In some cases usually in the older type of superheterodynes, regeneration adjustments were provided in one or more of the radio frequency stages, in some cases in the loop circuits. The adjustment of this regenerating condenser had a great deal to do with the satisfactory operation of the receiver in as much as incorrect adjustment resulted in an oscillatory state in the radio frequency amplifier and unnecessary heterodyning.

In some of the old type loop operated superheterodyne receivers where a radio frequency transformer was also used, a variation in frequency adjustment of the loop condenser and the radio frequency transformer condenser allowed the reception of the same station upon two points of the tuning control dial, providing of course that the intensity of the signal was sufficient to allow its entry into the radio frequency transformer, despite the fact that the loop tuning was set for some other frequency. In these receivers, the oscillator tuning control was a separate unit.

Volume Control in Radio Frequency Amplifiers

An examination of the wiring diagrams in figures 15 to 22 inclusive will afford an idea of various types of volume control systems employed. In many instances a dual acting control is used. This system functions to simultaneously vary the control grid bias and the signal voltage developed across the coil in the aerial circuit. The automatic volume control system, being utilized in conjunction with the intermediate frequency amplifiers is mentioned under that subject classification. Troubles in such tubes are discussed in Section 4 Part B. The adjustment of the automatic volume control system is discussed in Section 5 Part A.

Multi-Wave Radio Frequency Systems

The use of tapped coils to secure various frequency or wavelength ranges is shown in figure 7A. As yet there has been no announcement of a single unit superheterodyne which is of such design that a number of wavelength ranges are available. The types of systems used in the combination double oscillator circuits include tapped coils and plug-in coils. Where the coils are of the latter variety, a set are required for the input circuit and another set for the oscillator circuit. It is of interest to note that one manufacturer, Silver-Marshall have produced a multi-wave receiver wherein but one oscillator is used. This receiver intended for the European market covers the range from 200 to 2000 meters and does not enter the realm of short waves. The radio frequency transformer is located between the antenna and the 1st detector or mixer. The circuit is shown in figure 24.

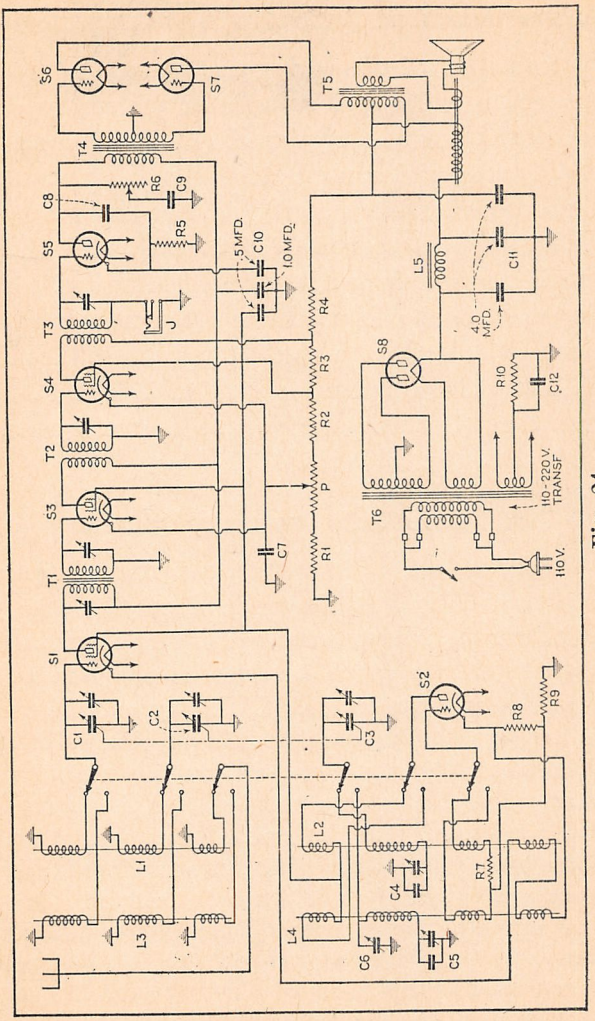


Fig. 24
Multi—Wave Superheterodyne

The 1st Detector, Mixer or Frequency Changer Tube

The function of this tube is to mix the incoming broadcast carrier and the beating signal. There are four types of mixer circuits. Perhaps the best method of describing these mixer systems is to consider them in the following light. Two resemble conventional detector circuits. One of these is identical to the grid leak-condenser arrangement and the second is identical to the grid bias detector. This is true irrespective of the type of tube used, that is, '01A, '27 or '24. As far as the modern superhets are concerned, the 1st detector or mixer is of the '24 grid bias type. Some use the variable mu tube. Examples of such circuits are shown in figures 25 and 26. In each case the tube functions solely

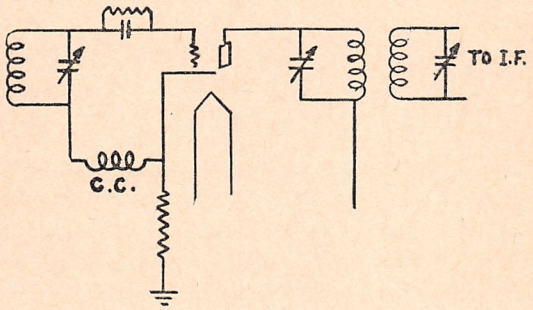


Fig. 25
Mixer Circuit

as a mixer. The energy from the oscillator representing the beating signal is fed into the mixer circuit via the coils marked "CC", as a rule located in the cathode circuit. This comment relative to the location of the coupling coil means the electrical connection. Its actual location is in coupling proximity to the oscillator circuits. In some of the older superheterodynes, the coupling coil was located in the grid return lead circuit,

either to ground or to the cathode or filament. In a few instances, the coil was into the grid lead between the tuned circuit and the grid condenser-leak combination. In some instances the signal from the oscillator is fed into the mixer tube via a series resistor-capacity circuit between the grid of the oscillator and the control grid of the mixer. In some instances, the coupling unit is a

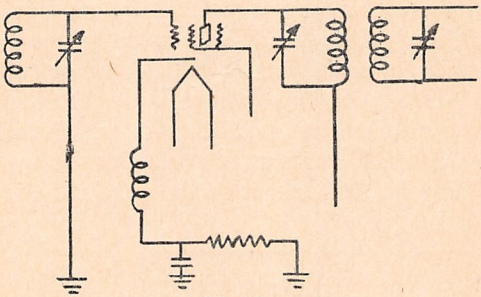


Fig. 26
Mixer Circuit

resistor. In other instances, the coupling is accomplished by placing the coupling coil in the screen grid circuit of the mixer tube. In a few instances, the coupling is inductive between a part of the oscillating circuit and the tuned input system of the mixer tube. In still other instances the coupling is via a small capacity connected between a tap upon the oscillator grid coil and the cathode of the mixer tube. An examination of commercial superheterodynes shows that the majority of the receivers connect the coupling coil into the mixer tube cathode circuit.

The second harmonic mixer system is shown in figure 13. Repetition of the diagram is unnecessary and the explanation given in Section 2 can be supplemented with the following: The system is of the grid bias type and only circuit A is associated with the selection of the incoming carrier. The fact that the tube functions as an oscillator is due to the coupling

between the plate and grid coils of circuit B. Inductive coupling exists between the two coils of circuit B but there should be no coupling between circuits A and B. The fact that the two circuits are tuned to widely differing frequencies enables satisfactory adjustment of each of the circuits but not always without reaction of the type which will influence the tuning of either.

Figure 26A illustrates the use of a recently developed input circuit. The circuit is tuned to the incoming carrier frequency and the location of this tap is such that the circuit is resonated to suppress the image frequency and keep it out of the mixer tube grid and the conditions arising because of the tap take care of the image frequency.

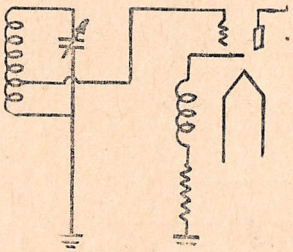


Fig. 26 A
Tapped input circuit for image frequency suppression

The Lacault Mixer

A deviation from the usual type of mixer circuit was that developed by R. E. Lacault. While it is true that this type of system never appeared in a commercial superheterodyne, it nevertheless was used in a large number of kit receivers known as Ultradynes. In this system the plate of the mixer tube is joined with one end of the oscillator coil and the voltage developed across the oscillator coil is utilized as the plate voltage for the mixer tube. The intermediate frequency transformer is in this lead. An idea of the circuit is shown in figure 27.

The Mixer In The Infradyne Receiver

In all the beat discussion thus far and in all other reference we have omitted mention of the fact that the output of the mixer tube contains the *sum* as well as the difference of the two frequencies fed into the tube. Thus if we feed a 100 KC carrier and an 800 KC oscillator signal into the mixer the plate circuit of that tube will show plate current variations at 1800 as well as 200 KC. The fact that a signal equal to the sum of the two frequencies appears in the plate circuit was utilized in the "Infradyne" receiver. This system developed during 1926, was quite popular upon the West Coast, the receiver being available in kit form. The beat note

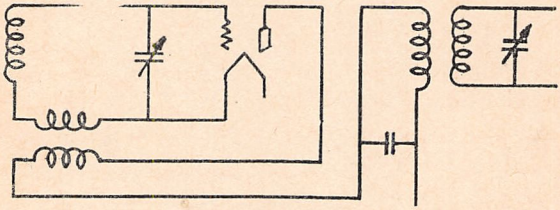


Fig. 27
Lacault Mixer System

employed was approximately 3500 KC. Another major difference with respect to the usual mixer circuit is that the signal from the local oscillator was supplied into the plate circuit of the tube by coupling the oscillator to a coil in the *plate* circuit of the mixer.

One of the claims made for this receiver based upon the numerical relations of the sum frequencies was that two point reception was impossible, since only one setting upon the tuning and the oscillator dials furnished the correct *sum* frequency. This of course does not take into consideration the possibility of a fairly strong second harmonic of a local station, in which case that

local station would be heard upon the fundamental and again when the complete receiver was adjusted to the 2nd harmonic of the fundamental frequency.

Recognizing The Method Of Coupling The Mixer To The Oscillator

There is no means of recognizing the method employed to couple the mixer to the oscillator without investigating the circuit continuity or examining the wiring diagram. If the latter is available, there is no need for tracing the circuit of the parts mounted upon the chassis.

The Mixer Tube Output Circuit

We made the statement during the discussion of the elementary generator and mixer circuit and also during the discussion of the mixer tube, that the beat note produced by combining the incoming broadcat carrier and the locally generated signal must be passed to the intermediate frequency amplifier. Further that the output circuit of the mixer tube contains a number of different frequencies, many more than can be imagined by reference to the simple illustration of the beat frequency waveform. Accordingly it evolves upon the unit located in the plate circuit of the mixer tube to select whatever frequency or frequency range is to be removed from the mixer plate circuit and passed to the intermediate frequency amplifier. This is accomplished by means of a tuned intermediate frequency transformer shown in the plate circuits of the various types of mixer systems illustrated in figure 25, 26 and 27.

As is evident both the primary and secondary circuits of this transformer are resonated. The resonant frequency is the required beat, the peak frequency of the intermediate amplifier. With the exception of the inter-

mediate frequency transformer to be found in the Lacault system, the primary winding of this transformer carries the plate current of the mixer tube. The currents representing the various component frequencies found in the plate circulate through the system, but by virtue of the resonating of the primary winding, the maximum voltage is developed across the coil at only the required frequency, all currents of other frequency having negligible effect.

It might be well at this time to mention briefly the frequency range determined by the presence of the modulating frequencies. An extended discussion of the tuning of the intermediate frequency transformers will be found under the heading "IF Transformers" in this section, but as an introductory note, we might repeat the statement made before that the beat note produced in the mixer circuit acts as a sort of carrier for the modulating frequencies present in the circuit. These modulating frequencies, which are reproduced as the audio signals by means of the loud speaker represent the side bands of the beat note. Therefore, it is necessary that the tuning of the intermediate frequency transformer located in the plate circuit of the mixer tube be such as to allow the passage of the modulated beat note including the sideband. Thus if the beat note is 260 KC, and the side band extends over 5000 cycles each side of this ficticious carrier, the width of the band pass is 10000 cycles or from 255 KC to 265 KC. Any condition which will cut the side bands means the loss of the higher audio register, either completely or in amplitude so that the audio output will not be a faithful reproduction of the original input. . . . Further details concerning the intermediate frequency transformers will be found elsewhere in this section. (See IF Transformers.)

The Oscillator

The function of the oscillator in the superheterodyne receiver is a very simple matter, at least it can be stated in that way. Its purpose is to generate a steady unvarying signal of a predetermined frequency, the exact value of which is determined by the constants of the circuit. However its operation in the receiver is another matter. Certain requirements must be fulfilled. These are: 1. Voltage substantially constant over the entire frequency band. 2. The frequency once adjusted must remain constant. 3. Minimum harmonic generation.

The frequency adjustment of the oscillator is such that it is at all times *higher* than the frequency adjustment of the tuned circuit by the value of the intermediate frequency. Thus if the intermediate frequencies for three different manufactures of receivers are 130, 175 and 260 KC, the oscillators in these three receivers will generate waves of the RF or mixer tube circuits. There is a definite reason for tuning higher than the incoming carrier. This is the decrease in the range of the oscillator tuning circuits. Examples are as follows. Suppose that the receiver tuning range is from 1500 to 550 KC. If the IF frequency is 175 KC and the oscillator is adjusted 175 KC higher than the carrier, the tuning range of the oscillator circuit extends from 1675 KC to 725 KC. This is equal to a ratio of about 2.3, but if the oscillator is adjusted 175 KC *lower* than the carrier, the tuning range required to cover the stated broadcast band is from 1325 KC to 375 KC, a ratio of slightly more than 3.5. The shorter range enables economy in construction and simpler design of the circuit. As a point of information let it be known that it is common practice in all commercial receivers to adjust the oscillator to a frequency higher than the associated carrier by the value of the intermediate frequency.

Types of Oscillator Circuits

The operation of all tube oscillators of the conventional type is based upon energy feedback. If energy from the plate circuit is fed back into the grid circuit

in correct phase relation, and the feedback is of sufficient magnitude, the tube will become a generator of sustained oscillations. The frequency of the oscillations is determined by the constants of the tube circuit.

The method of securing feedback is by coupling the tube plate circuit to the tube grid circuit, i.e. the output. (This is not true in the case of the dynatron oscillator). Several methods of coupling are available. These may be listed as 1. The internal grid to plate capacity of the tube; 2. Inductive coupling between the plate and grid circuits; 3. Capacity coupling between output and input; 4. Resistance—capacity coupling. Of these four systems, the most commonly employed in superheterodynes is inductive coupling. Examples of these circuits as used in existing superhet receivers are shown in figures 28, 29, 30 and 31. The electrical values of the units are not necessary in as much as they are shown upon the complete wiring diagrams which appear in the Perpetual Trouble Shooter's Manual and in some of the complete circuits shown herein.

All of these circuits are similar and used plate feed back by means of inductive coupling. There are however some differences. Thus in figure 31, we find that the major tuned circuit is inductively coupled to the grid and plate coils. The circuit is utilized as a "tank" and is inductively coupled to the grid and plate. Since the tuning of the system is that of the "tank" and since this tank is not connected directly to the tube circuit any tendency towards frequency instability is overcome. The frequency of the system is determined solely by the constants of this circuit.

Figures 29 and 30 differ from the rest in that a capacity-resistance combination is utilized in the grid circuit. The purpose of such circuits and the use of resistors in these circuits is to minimize harmonic generation. (The reason for suppressing harmonic genera-

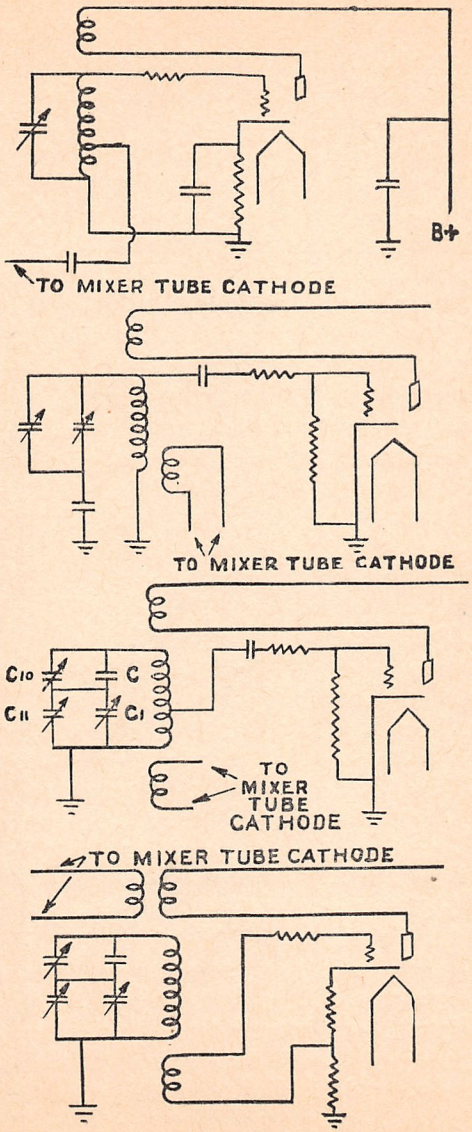


Fig. 30
Superhetodyne Oscillators

tion was explained in connection with beat notes and the troubles experienced through undesired heterodyning. In figure 28 is shown the use of a condenser to couple the oscillator to the mixer circuit. In the remainder of these drawings, the coupling coils are inductively coupled to some part of the oscillating circuit. As a rule the physical location of these coils is upon the form which also carries the remainder of the oscillator circuit inductances.

The four condenser tuning circuits shown in figures 30 and 31 are not as intricate as they appear. The major tuning condensers, say in figure 30 are C and C1. Condensers C10 and C11 are trimmers utilized to balance the circuits at the lower and upper ends of the scale. By a suitable selection of C, the total capacity across the oscillator coil is kept at such a value as to result in the correct frequency adjustment of the oscillator. In some cases only one trimmer is used.

The dynatron oscillator makes use of the screen grid tube. This type of tube ('24) has a peculiar plate current-plate voltage characteristic. In the range of plate voltage between say 10 and 40, the plate current decreases rather than increases as the voltage is increased from the lower limit. This means that the plate resistance is negative, due, to the emission of secondary electrons from the plate and which are attracted to the screen by virtue of the higher voltage applied to that element. Any device which possesses negative resistance characteristics, will, provided certain other conditions are satisfied, produce sustained oscillations. If a parallel tuned circuit is connected into the plate circuit of a screen grid tube and the tube screen and plate potentials are of the proper order and the impedance of the tuned circuit is equal to or greater than the negative resistance of the tube, the tube will generate sustained oscillations of a frequency determined by the constants of the

parallel circuit. An example of this circuit as used in a commercial superheterodyne is shown in figure 32. An examination of this circuit shows that the tube was utilized as a combination mixer and oscillator. The intermediate frequency transformer is connected into the screen grid circuit. The oscillations are governed by the constants of the parallel circuit in the plate system. The beat note is produced within the tube and passed into the intermediate frequency amplifier through the screen grid circuit. There are several other adaptions of screen grid oscillators, not necessarily of the dynatron type.

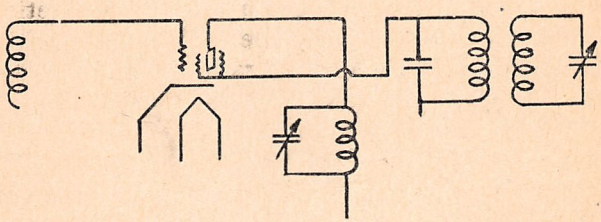


Fig. 32
Dynatron Oscillator—Mixer

Radiation From Oscillator Coils

Although this subject should be a part of the discussion covering trouble shooting, reference at this time should be of value. The oscillating circuits used in such generators are radiators of high frequency energy, consequently shielding is desired and required. Another item in connection with such oscillators is that when used in receivers which do not employ a radio frequency amplifying stage ahead of the mixer, radiation of an interfering wave from the aerial is possible, unless careful precautions are taken in the form of several independent pre-selector circuits.

Power Output of Oscillators

There are certain power requirements of superheterodyne oscillator circuits. Since the signal amplitude fed into the intermediate amplifier is governed to a certain extent by the amplitude of the oscillator output, one would imagine that the greatest possible output is desired. Such is not the case. Care must be taken not to overload the mixer tube. Then again it is necessary to bear in mind that the greater the power output of the desired fundamental, the greater is the output upon the harmonic frequencies, a condition which should be avoided.

A requisite of the oscillator is that it function with uniform amplitude output over the entire tuning scale, although it is possible to arrange a circuit whereby a non-uniform output is secured in the order to compensate for inequalities in the sensitivity of the remainder of the receiver. Arrangements of this type are used. However it is something beyond the scope of general service work and we make this statement with the intention of dissuading those men who may think that some ordinary change made upon the oscillator system will compensate for some peculiar weakness of the receiver.

Troubles and trouble shooting in oscillator systems are discussed in Sections 4, 5 and 6.

The Intermediate Frequency Amplifier

The function of the intermediate frequency amplifier to amplify the modulated beat note produced by mixing the incoming broadcast carrier with the locally generated signal. We made the statement that this signal can be classed as a newly created carrier. If we consider the action taking place in the intermediate frequency amplifier, the signal does approximate that of

a modulated carrier because the intermediate frequency amplifier is nothing more than a radio frequency amplifier operating upon a long wavelength. The term "intermediate" to designate frequency is simply an expression employed to differentiate between radio frequency and audio frequency, in as much as the frequencies found in the intermediate amplifier are located between the lower radio frequency limit and the upper audio frequency limit.

Embarking upon the discussion of the intermediate frequency amplifier we are concerned with an amplifier which differs from the radio frequency amplifier in nothing but the frequency adjustment. The types of tubes used are identical in both cases. The method of applying voltages is likewise identical. The difficulties which arise relative to tuned circuits are identical in the intermediate and radio frequency amplifiers. Thus if you can visualize a radio frequency amplifier which has tuned circuits in the form of transformers which are resonated to say 180 kilocycles instead of 1000 kilocycles, you have the intermediate frequency amplifier.

Naturally there must be some difference between the two amplifiers. This difference is purely a matter of individual coupling unit design and the frequency adjustment. Whereas the tuned radio frequency amplifier offers continuously variable tuning over whatever frequency spectrum is desired, the intermediate frequency amplifier offers tuning upon but one frequency. The need for side band passage in the tuned radio frequency amplifier exists in identical manner in the intermediate frequency amplifier. Thus if a radio frequency amplifier is designed to allow 10 KC band pass, the intermediate frequency coupling unit likewise is designed to allow a 10 KC band pass; 5 KC each side of the resonant frequency. If sideband suppression in the RF system interferes with quality, just so does side band limitation in

the IF amplifier interfere with quality of reproduction.

With very few exceptions, the design of the intermediate frequency amplifier is the same in all superheterodyne receivers. By this statement we mean that the circuit design is alike. There are of course certain variations, as will be shown later, but the general structure is the same. An investigation of intermediate frequency amplifiers used during the past 10 years in superheterodyne receivers show changes to be conspicuous by their absence. Thus if you become familiar with the general structure of an intermediate frequency amplifier, that knowledge is applicable with but few variations to all intermediate frequency amplifiers utilized in superhet receivers.

Examples of circuit design employed in the IF amplifier are shown in figures 33, 34 and 35. The major difference is in the design of the intermediate frequency transformers. The circuit shown in figure 33 is con-

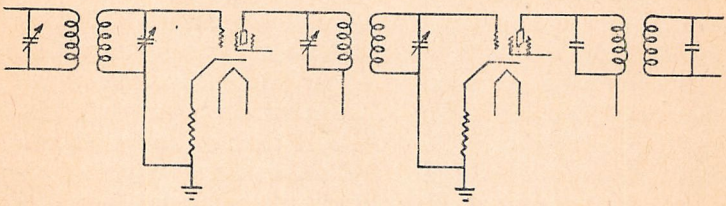


Fig. 33
Intermediate Frequency Amplifier

ventional, illustrating the use of tuned primary and tuned secondary circuits. In figure 34, one of the intermediate transformers employs three windings in place of the usual two. One of these L1, functions as the link between L and L2 and has the tendency of affording greater selectivity and greater control of the passage of none other than the desired 10 KC band pass at the predetermined frequency. In figure 35, we note

the use of a capacity coupled intermediate frequency transformer with tuned secondary and untuned primary. In all other respects the circuit is the same.

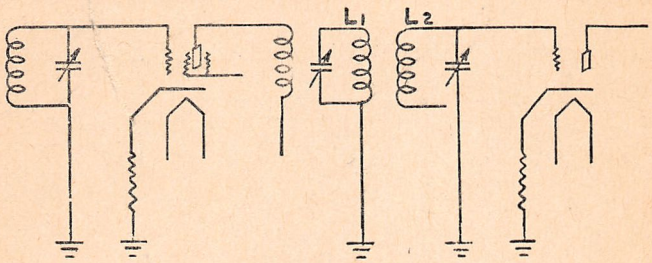


Fig. 34
Three winding IF transformer system

The number of stages of intermediate amplification employed is a matter of individual design. Three stages was customary at the time that the superheterodyne came out of obscurity. At the present time, in fact ever since its popularization, the IF amplifier seldom employed more than two stages. In midget sets the number seldom exceeded a single stage. Since a high degree of selection is desired in the intermediate frequency amplifier, it is customary to tune both the primary and secondary circuits. As is evident in figure 34, two circuits are tuned in the three coil transformer. There are of course instances where only the secondary is tuned but these are rare.

Thus, the man confronted with the problem of aligning an intermediate frequency amplifier can consider that he must check four circuits in a single stage system and six circuits in a two stage IF amplifier. If three stages are employed, eight such circuits will have to be aligned. Now, in connection with such tuned circuits, variable condensers are usually used. These condensers are adjustable in the field, but there are cases where

despite the use of tuned primary and tuned secondary systems, only the secondary circuit is adjustable in the field. The primary circuit while adjustable is definitely adjusted at the time the receiver is made and further alignment is not possible. However, such conditions seldom exist in any but one stage of the IF amplifier.

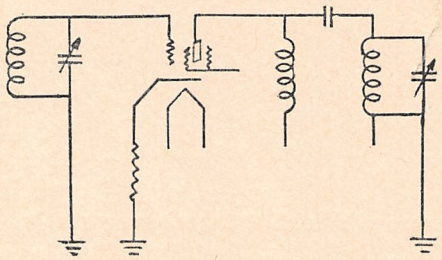


Fig. 35
Special type IF transformer

With few exceptions modern intermediate frequency transformers employ separated primary, secondary and when used, link windings of the honeycomb, lattice or similar variety. The coupling between these circuits is definitely adjusted at the time that the transformer is manufactured and further adjustment of the coupling is not made out in the field. The only work to be done upon such transformer from the service angle is accurate alignment of the respective tuning condensers.

Tubes Used in IF Amplifiers

The types of tubes used in the IF amplifier are exactly those suitable for use in the radio frequency amplifier. Modern receivers make use of the screen grid and variable mu tube, thus achieving a high degree of amplification per stage. Amplification as high as 80 or 90 per stage is not uncommon.

Characteristics of IF Amplifiers

If you recall the previous discussion relative to selectivity, the tuning of the intermediate frequency amplifier contributes very greatly to proper adjacent channel selectivity. Any deviation from accurate resonance is harmful in ways practically identical to that to be found in an "off resonance" tuned radio frequency amplifier. By the same token, conditions which will tend to cause abnormal sharpness in tuning will be harmful in the manner to be experienced with tuned radio frequency amplifiers. Whatever items associated with a tuned radio frequency amplifier will cause low response, poor quality of reproduction, lack of selectivity, etc., must be accorded attention in connection with intermediate frequency amplifiers.

The peak frequency adjustments of modern intermediate frequency amplifiers cover quite an extensive range, although the majority are rated at 175 KC. The full range extends from about 130 to about 460 KC, with specific values as follows: 130 KC., 172.5 KC., 17 KC., 177.5 KC., 260 KC., 262 KC. and 460 KC. The ones which differ from the majority and stand out as exceptions at the time of this writing are 130 KC in the Atwater Kent receivers; 172.5 KC in the Sparton receivers, 177.5 KC in the Stewart Warner receivers, 260 KC in the Philco receivers and 262 KC in the U. S. Radio and Television receivers. The 460 KC setting is used in some kit receivers. The majority of the superheterodynes in use today employ 175 KC intermediates. The older receivers manufactured during 1923-1926 employed, 30, 40 and 115 KC.

Although the time is ripe for a discussion of pickup by the intermediate frequency amplifier we shall reserve that discussion for Section 4. Let it suffice to say that total shielding of the IF transformers is absolutely essential to good operation of the complete receiver.

Selection of The Intermediate Frequency

This item is included more as information rather than data which may be of practical value to the service

man. In view of the fact that the design of the IF transformer is based upon the predetermined IF frequency, what will follow is not intended to convey information whereby the service man can change the intermediate frequency of a superheterodyne in order to conform with some personal opinion or idea. The choice of the intermediate is a compromise between amplification and selectivity. We have shown how the lower the value of the intermediate frequency, the greater the adjacent channel selectivity and the possible stable amplification. On the other hand the higher the intermediate frequency, the greater the freedom from image frequency troubles. What with the various parts of a receiver which contribute to some of these troubles, design engineers have by due consideration of each of these problems, selected IF frequencies between 130 and 262 KC. Experiments have shown that the major harmonics to be considered in connection with interference problems due to coupling between the demodulator plate circuit and the mixer tube are the 2nd and 3rd. By selecting an intermediate frequency which will have its 2nd and 3rd harmonics fall outside of the regular 1500-550 KC broadcast band, much interference trouble will be eliminated. By exercising suitable precautions, trouble due to the 3rd harmonic of the 260 and 262 KC intermediates, which fall within the broadcast band may be minimized. For that matter the same is true of the 2nd and 3rd harmonics of the 460 KC signal but since the 2nd harmonic in the demodulator tube is the stronger of the two and since this frequency falls within the broadcast band, interference is more likely to occur and extreme care must be taken in the design and layout. Then again, the higher the frequency, the less the stability assuming a constant value of gain per stage.

The Second Detector

The second detector or demodulator in the superheterodyne receiver is no different from the usual detector in any modern receiver. Its primary function is to demodulate the modulated beat note. In other words to separate the audio frequencies from the intermediate frequency carrier. Since this book takes for granted that the reader is familiar with the components of the average TRF receiver, therefore with the usual detector systems, very little space need be devoted to the explanation of this subject. However special mention must be made of the systems wherein the second detector is also the automatic volume control tube. It shall follow after the description of pertinent items relating to the demodulator tube in the superhet.

With very few exceptions the demodulator tube is operated as a negatively biased detector of the "power" type. The input circuit to such tubes is usually but not always of the tuned type, since in the majority of cases, an intermediate frequency transformer couples the last or the only IF tube to the detector.

An important consideration in connection with the usual second detector (demodulator) tube is the RF choke or low pass filter system located in its plate circuit. Two types of such filter systems are shown in figures 36 and 37. In the former the filter system consists of the choke RFC and the bypass capacity C. In figure 37 the system consists of the choke RFC and the two bypass capacities C and C1. The function of this circuit is to prevent the passage of the intermediate frequency and the associated harmonic currents from finding their way into the audio frequency transformer or whatever coupling device is used in the detector plate circuit.

Imperfect operation of this circuit is apt to cause annoying difficulties in the form of noise and possibly in-

terfering signals. The latter condition may be experienced if the bypass condensers are open circuited or if the choke RFC is short circuited. The choke is also of

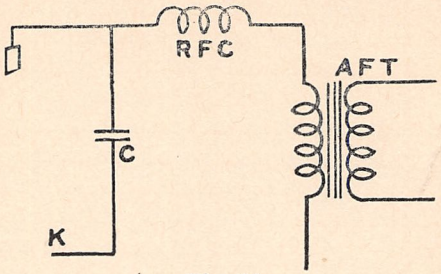


Fig. 36
Filter in demodulator plate circuit

importance as a means of linking external leakage currents with the signal currents flowing in the plate circuit, thus causing the production of a heterodyne signal in the audio system and the speaker. Great care must be exercised to assure that the detector plate circuit choke is not coupled to any part of the RF amplifier, oscillator, mixer or intermediate frequency amplifier.

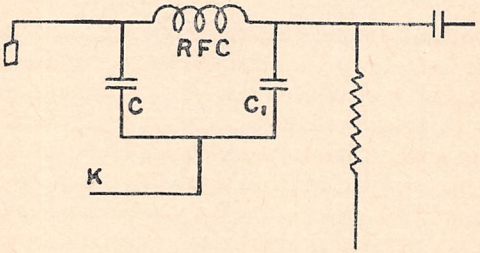


Fig. 37
Filter in demodulator plate circuit

In some instances, this choke like some of the RF and oscillator coils is shielded and a good ground contact is considered as being essential to good operation of the system.

Combination Detector and Automatic Volume Control

An explanation of the various types of automatic volume control circuits used in existing commercial receivers may be found in the Perpetual Trouble Shooter's Manual and in Practical Radio Repairing Hints both books written by the author. Additional data is given in subsequent paragraph under the heading 'The Automatic Control Tube''.

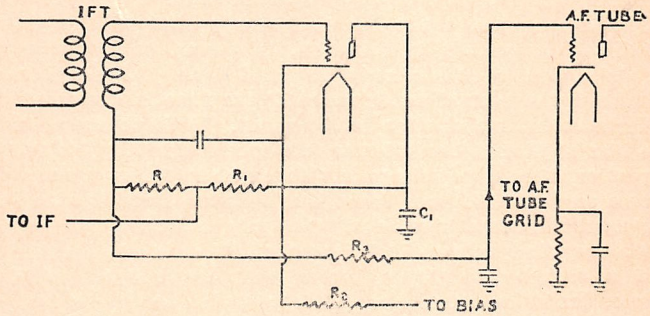


Fig. 38
Diode AVC and Demodulator

In a way, this dual acting tube can be considered as a two element rectifier, comparable in operation to the standard rectifier such as the 281. Of course the operating voltages and the character of the voltages is different. In operation this demodulator acts as a linear rectifier, meaning that the output audio frequency voltage is proportional to the input RF voltage.

The tube usually used in this position is a '27 and a sample circuit as used in some receivers is illustrated in figure 38. The plate and cathode are joined. The IF transformer is of the untuned type because during one half of the signal voltage cycle current flows through the secondary winding and the circuit is highly damped. This would nullify all the advantages of tuning to resonance, hence the transformer is not tuned in usual fashion. During the positive halves of the signal voltage the rectified current flows through the resistances R and R1. This current contains the audio frequency component.

Further the flow of this current through these resistances develops a voltage across them. By suitable selection of the values for R and R1, any desired value of voltage is available at the tap upon the lead joining these two resistors. This lead joins the grid circuit of the intermediate frequency amplifier tube. As is evident it is a part of the circuit which includes filter resistor R2. This resistor connects to a part of the voltage divider whereby the correct steady grid bias is applied to the intermediate frequency amplifier. The polarity of the voltage developed across R1 is such that it is additive to the steady normal bias applied to the tube.

The greater the signal voltage, the greater is the voltage developed across the combination. However, only that across R1 is added to the steady IF grid bias. As the bias is increased, the mutual conductance of the tube is decreased and a decrease in amplification is the result. With no signal input, the bias applied to the intermediate tube is fixed by the voltage apportioned in the voltage divider system. The resistor R2 serves only as a filter or decoupling resistance and has no bearing upon the actual numerical value of the bias.

The rectified voltage is fed to the AF tube via resistor R3 and a capacity serves to bypass the intermediate frequency carrier and its harmonics, thus allowing only the desired audio frequency voltage to act upon the grid of the 1st AF amplifier tube. The capacity C1 functions in conjunction with R2 as a resistance-capacity filter so as to keep the rectifier currents and possibly RF out of the voltage divided system.

AF Units Located In Demodulator Plate Circuit

Reference to figures 36 and 37 is apt to create the impression that only resistance or transformer coupling may be utilized in the demodulator plate circuit. Let it be understood that any type of audio frequency coupling is applicable to the regular type of demodulator. Furthermore, that the two condenser filter system shown in figure 36 is applicable to any type of audio frequency coupling unit and not only when resistance coupling is employed.

The Audio Frequency Amplifier

Once again we encounter a system within the superheterodyne receiver which is identical to that found in

any TRF receiver. Therefore it is unnecessary to delve into an extensive discussion of just what takes place in this system. The only possible exceptions to this statement are those audio frequency systems which are not conventional or those which have become popular or have been placed in use for but a short time.

The function of the audio frequency amplifier is to increase the amplitude of the audio frequency voltages secured from the demodulator tube so that ample sound output is secured from the loud speaker. The types of audio frequency systems utilized in superheterodynes are no different from those employed in TRF receivers. However, a few modifications may be found in superhets and these shall receive attention. Reference to the Perpetual Trouble Shooter's Manual will show the many types of audio frequency amplifying systems which find daily use. The special systems are listed herein. Those systems which are conventional in design but introduce certain complications during testing will be found in Section 7.

An example of a resistance coupled audio amplifier which is used in some superhets is shown in figure 39. Another example of a resistance coupled system as used in the audio output stage is shown in figure 40. The resistor R is referred to in connection with overloading of the pentode stage and the development of buzzing sounds and fluctuating reception. Another resistance coupled system equipped with tone control is shown in figure 41. Transformer coupled systems are of the conventional type. An example of the Loftin-White direct coupled system, which while not yet found in commercial superhets, does appear in a few kit receivers is shown in figure 42. The resistor R is common to the plate circuit of the first tube which may be the demodulator and also to the grid circuit of the audio tube, which may be the output tube. Obviously the conventional set analyzer test is not applicable. A point to point test must be made in order to determine the voltage present across the respective circuits and the test must be made without signal input.

The Automatic Volumn Control Tube

There have been many claims made for the automatic volume control tube. Primarily its function is to keep the signal output to the receiver at substantially uniform level providing that the signal input has a definite minimum. It will mitigate fading providing that the intensity of the broadcast signal at its lowest point is of sufficient value to be within the sensitivity limits of the receiver. If the signal decreases to such levels that it is too weak to operate the amplifiers, the signal will fade out despite the automatic volume control. On the other hand the use of the AVC tube does eliminate blasting during the

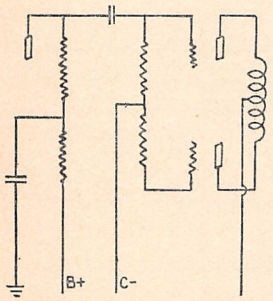


Fig. 39
Special Audio Output System

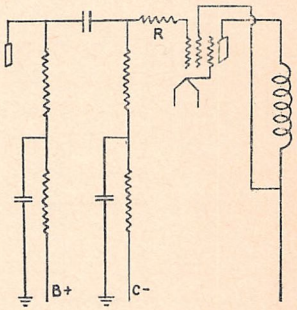


Fig. 40
Pentode Output with grid suppressor resistance R

tuning of stations. Strange as it may seem, a receiver utilizing automatic volume control can be recognized by an increase in noise level during the time that no station is tuned in.

Two types of automatic volume control circuits are used in the modern superhet. One consists of the combination diode demodulator and automatic volume control. See figure 43.

The plate voltage is supplied by the signal from the intermediate frequency system. During the passage of the signal

the plate is positive with respect to the cathode during one half of each cycle. During this half of the cycle current flows through the tube circuit and through the resistance

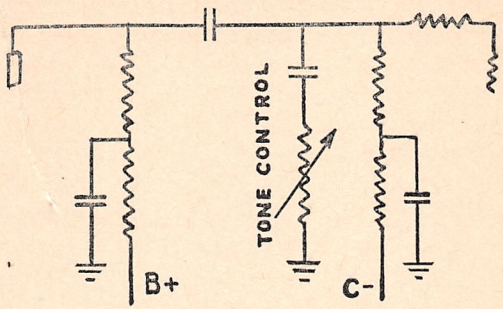


Fig. 41
Audio Amplifier with tone control

network R and R1. These two units constitute a voltage divider. If you will note, the cathodes of RF and IF tubes go to ground and that one point of the voltage divider goes to ground. Also that the grounded point of the divider goes to ground. Also that the grounded point of the divider is not the most negative point. The arrow indicates the return to the end of the power pack rectifier system and this lead also returns to the midtaps upon the heater windings.

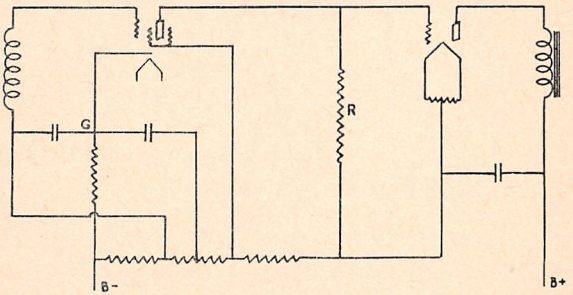


Fig. 42
Loften—White Audio Amplifier

If you consider the location of the ground terminal of R4 in the voltage divider and the grounding of the RF and IF cathodes you will note that these points are positive with re-

spect to the junction of the resistor R5 with the resistor R4. Now, if you follow the path of the circuit from RF to the cathode of the AVC tube, through R and R1, then through R2 to the grid of the IF and through R3 to the grid of the RF tube, you will realize that the IF and RF grids are negative

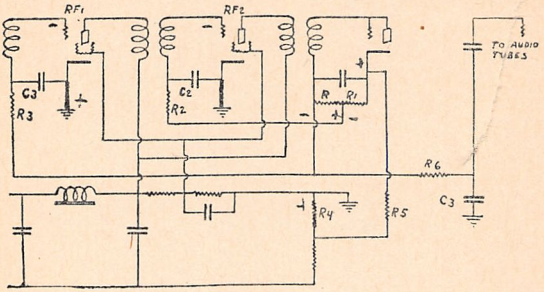


Fig. 43
Diodi Demodulator and Automatic Volume Control

with respect to their grounded cathodes. Without a signal input into the receiver, the minimum bias applied to the IF and RF tubes is determined by the value of R4.

Now, if a signal is applied and current flows through R and R1, a voltage drop will be produced across these resistors, and

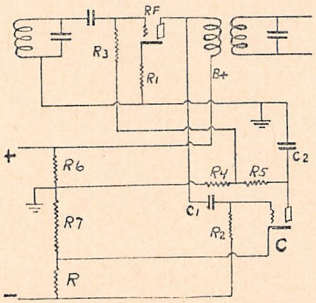


Fig. 44
Automatic Volume Control

the polarity of these voltages is positive at the cathode end and negative all along R and R1 away from the junction between R1 and the cathode. By suitably tapping R-R1 as for example the connection from R2, the voltage developed across R1 is

added to the regular bias, thus increasing the bias applied to the IF tube. By the same token and the connection of R3 to the end of R, the total voltage across R-R1 is added to the regular bias and is applied to the grid of the RF tube. The resistors R2, R3 and R5 are ordinary filter resistances to keep RF currents out of the circuits where they do not belong. The greater the voltage out of the IF transformer and applied across the AVC tube, the greater the current through R-R1 and the bias applied to the RF and IF tubes. The design of the system arranges for the proper equilibrium to be reached. The audio frequency of the rectified signal is fed to the audio amplifier through R6. The bypass condenser C3 bypasses the radio frequency component in the rectified signal.

Another example of an automatic volume control tube is shown in figure 44. In this instance the function of the tube is solely that of automatic volume control by causing a variation of the control grid bias, either upon the IF tube or upon the RF tube depending upon the design of the receiver.

An examination of the circuit shows that the steady no signal bias for the RF or IF tube is secured by means of the cathode resistor R1 and this voltage reaches the grid through the circuitous path R3 and R4. We also note that the AVC tube secured its steady operating potentials from the voltage divider. We note that the junction of R6-R7 goes to ground and that the plate of the AVC tube connects to this point through R4-R5. One would be tempted to ask about the operating plate voltage. If you examine the voltage divider system you will note that the grounded point upon the divider is not the most negative. The low end of resistor R is the most negative, which means that any point upon R, R7 and R6 away from the low end of R is positive. Thus the plate of the AVC tube secures a positive potential, because the junction between R6-R7, although grounded is still positive with respect to R. Furthermore the cathode of the AVC tube is connected to the junction between R and R7. Also that the grid return of the AVC tube is to the low end of R. There exists therefore a potential difference across R, which is the grid bias and also the potential difference between the grid and cathode of the AVC tube.

Further examination discloses that the grid of the AVC tube is joined with the plate of the IF tube through the condenser C1. By properly choosing the voltage across R, the correct bias is secured so that the plate current in the AVC tube is

almost zero. Futher examination also shows that two resistors R4 and R5 are in the plate circuit. Also that a tap upon this resistance network joins the grid of the IF tube through the resistor R3. If a signal voltage is applied to the grid of the AVC tube, current will flow through the plate circuit, therefore through the resistors R4 and R5. As is to be expected a voltage is developed across these resistances. Because of the tap connection to R4-R5, the voltage developed across R5 is applied to the grid of the amplifying tube and this voltage is of such polarity that it is additive to the normal steady no-signal bias and the total negative bias applied to the amplifying tube is increased. The greater the signal voltage applied to the AVC tube, the greater the bias applied to the amplifying tube. The design of the electrical values of resistance determines the equilibrium of the circuit.

Still another type of automatic volume control operates simultaneously with the signal applied to the demodulator grid. In this type of circuit, the plate current of the AVC tube flows through a resistor which is located in the electrical circuit that the voltage developed across it is the grid bias for the RF or IF or both tubes. By properly adjusting the bias for the AVC tube, the plate current is set at such value that the correct steady no-signal bias is applied to the amplifier tubes. When a signal is passed into the demodulator tube, it also swings the grid of the AVC tube, causes an increase in plate current and an increased drop across the bias resistance for the amplifiers. The result is an increased bias upon the amplifier tubes and a reduction of amplification as in the other instances. A setting of the volume control, (which means the setting of the bias for the AVC tube), so that the AVC tube plate current is very low, means minimum bias upon the amplifying tubes and greatest sensitivity. An adjustment for high AVC tube plate current means maximum bias for the amplifiers and minimum sensitivity.

Due recognition of the function of such devices shows that unless supplementary volume control is used, the receiver jumps to maximum sensitivity during the time

that no signal is tuned in and during the moments when one is tuning between stations. The effects of such a condition are mentioned in Section 8, during the discussion of the elimination of noise.

The Visual Tuning Meter

The function of the tuning meter is to show the adjustment for maximum resonance. Its basis of operation is the variation in tube plate current as the AVC tube varies the grid bias. The meter is connected into the plate circuit of one or more tubes or into the cathode circuit of these tubes. When the receiver is turned on, and no station is tuned in plate current flows through the amplifier tube circuits. Therefore the steady plate current is indicated upon the meter. However, as a station is tuned in and the AVC tube commences to function, the increased bias reduces the plate current and the closer the tuning adjustment to resonance with the incoming station, the greater the bias developed by the AVC tube and applied to the amplifier. This means that the amplifier tube plate current is reduced the maximum amount. Thus if the meter were connected in normal fashion, the greater the reduction in plate current indication the closer the tuning to resonance. However such action of the meter is apt to be confusing, that is correlation of a reduction in plate current with maximum resonance. What is done is to reverse the scale so that when the state of no signal and maximum plate current exists, the pointer moves across the scale and comes to rest at zero. This is the position of the meter with no signal input. As the receiver is tuned the meter pointer gradually moves across the scale towards the higher scale readings and is maximum at absolute resonance. *It is necessary to bear in mind that the amplifier tube plate current is actually de-*

creasing as the meter pointer moves towards the higher indications upon the scale.

Obviously such a system should interfere with the proper adjustment of a band pass circuit, wherein maximum resonance would. be indicated over the width of the band pass. However the tuning of the modern superhet sufficient peak upon the IF frequency to enable an accurate adjustment by means of the tuning meter. As far as service tuning adjustments are concerned, the meter should be short circuited and the output meter employed during the alignment adjustment.

Local-Distance Switches and Tone Controls

The function of the first named unit is two fold. In the first place it serves as a means of reducing the sensitivity of the receiver when tunning to local stations, thus minimizing possible interference. The second is to minimize tube overloading and the troubles which accompany such a condition. With the development of the variable mu tube, this switch is being dispensed with. Another supplementary function of the switch is to broaden the selectivity of certain circuits so as to improve the fidelity of reproduction.

Such "local-distance" switches are to be found in different parts of the receiver and to be of varying type. In some cases they are located across the antenna system and may do nothing more than disconnect the antenna or shut a capacity across the antenna coil. Sometimes a resistance across the antenna coil. In other systems a fixed resistor is shunted across an RF transformer primary or across an IF transformer primary. In still others it introduces a resistance into the RF or IF tuned secondary circuit.

The tone control as a rule consists of a fixed condenser connected in series with a variable resistance. The loca-

tions are various. The modern super with pentode output locates this control system across the input circuit. When connected across the output circuit it is said that the constants are selected with the idea of minimizing the third harmonic. By proper selection of the load impedance applied to the output tube, the second harmonic is minimized. Its primary function no matter where located is to enable the receiver owner to reduce the intensity of the upper audio register and produce tones which may suit his personal fancy.

Section 4

TROUBLE SHOOTING AND SYMPTOMS ENCOUNTERED IN SUPERHETERODYNES

The process of repair consists of two actions, namely "trouble shooting" and "servicing". The former includes the analysis of the symptom and the isolation of the defect, whereas the latter includes, the repair, adjustment or replacement, whichever of these must be done.

In view of the fact that this book is not intended as a course of study covering radio service in general and since we take for granted that the reader of this work is familiar with general service procedure, it will not be necessary to embark upon a routine discussion of general radio service. The contents of the "Perpetual Trouble Shooter's Manual" will supply many of the general details absent from the pages of "Servicing Superheterodynes". Recognizing that the audio amplifier, speaker and power pack utilized in superheterodynes is no different from that employed in the conventional TRF receiver, special discussion covering those units likewise is unnecessary. However those special items which represent the difference between the superhet and the TRF receiver will receive the required attention. We feel that this type of presentation eliminates all duplication of effort and enables a concise presentation of the pertinent facts.

Equipment Essential For Superheterodyne Trouble Shooting

Four pieces of apparatus are essential for superhet trouble shooting. These are:

1. A set analyzer, set tester or diagnometer of sufficiently modern design to accomodate the screen grid tube, the variable mu tube and the pentode tube.
2. An RF and IF oscillator capable of producing sustained oscillations, self modulated or modulated by a separate tube, with a frequency range or 1500 to 550 KC for broadcast work and a range of from 260 to 125 KC for intermediate frequency adjustments.
3. An output meter or some device for use as a signal output indicator.
4. An ohmmeter or a device suitable for the rapid measurement of resistance.

In some instances, depending upon the design of the unit, the output meter may be a part of the oscillator, therefore a separate unit will be required. The same may be true in the case of the ohmmeter, which may be a part of the set analyzer or tester. As to the RF and IF oscillator a single unit can be utilized to cover both bands. By designing the oscillator circuits to cover the IF band, the harmonics of the various frequencies within this band can be employed for broadcast frequency alignment. How this is accomplished is described in the section devoted to the design of the RF and IF oscillator.

It is possible to dispense with all of this apparatus, by utilizing a broadcasting station as the source of the required signal and a high resistance voltmeter-battery combination for all checking, but the practice is not recommended because the required rapidity and accuracy of operation are not secured. The actual application of set tester, oscillator output meter and ohmmeter are described during the discussion of the actual servicing.

Trouble Shooting

There exists a difference of opinion relative to the first step to be taken when a defective receiver must be repaired. It is our opinion, which has been verified by repeated tests in practice that the *first step is a routine test of the tube operating voltages and currents.* The reason for this statement is founded upon the fact that such a routine test is imperative no matter how trivial the defect, even if it is a grounded aerial, which as you know has no connection whatsoever with a defect in the receiver. Every service call must include the tube voltage test for several reasons. First, because it will indicate the condition of the tubes. Second, because it may indicate the development of a minor defect, which if allowed to exist for a prolonged time will eventually result in a major defect. Third, the results of such a test will help in the isolation of the defect and will materialy reduce the number of operations required to locate the fault.

We assume that a voltage test has been made and the findings have been recorded. The next step depends entirely upon what conditions are indicated by the voltage and current tests. This is true irrespective of the symptoms manifested by the radio receiver. If any one circuit shows incorrect operating voltage, the first thing to be done is to determine why that state of incorrect plate, screen, heater, grid or cathode voltage. If one circuit shows total lack of voltage, the first step is to determine why such a condition exists. Such tests are described in section 7. Since the actual testings is the subject of a separate section of this book, we can proceed after taking for granted that the receiver is defective, yet the operating voltages appear normal. With this condition as a basis we shall consider various symptoms and the contributing causes when the operating voltages are normal. Each of the symptoms and causes to be outlined

until other specific mention is made, have no influence upon the values of the tube voltages and currents.

Symptoms And Contributing Causes

In this listing we shall make brief mention of the possible reasons for the condition and you are to take for granted that the parts of the receiver referred to must be checked.

1. Interfering Signal Is Of A Frequency 10 KC Away From The Desired Station. This is a case of "adjacent channel" selectivity. The contributing causes may be:

a. Incorrect tuning of the IF transformers. (Make certain that all are peaked at the correct setting. However you must recognize in the case of flat-top tuning characteristic systems, that the peak will not always be at the rated frequency.)

b. Check the position of the aerial to assure that there is no coupling between the aerial and the RF system.

c. Imperfect shielding. See that the shield and shield base contacts are firm.

d. Slightly incorrect adjustment of the tuning condenser trimmers. (This condition is problematical because an "off resonance" condition will interfere with the signal output.)

e. Slightly incorrect adjustment of the oscillator trimmer. (This too is problematical for the same reason given at "d". A possible exception is such a problem at the lower or upper limit of the dial.)

f. Excessive signal strength from the interfering station. (This includes operation of the volume bias at such a value that the RF tube or the IF tube no longer operates as an amplifier. If operation at a high volume level seems to improve conditions, one remedy is to reduce the aerial length.)

g. Incorrect lineup of the oscillator condenser is apt to cause such a condition and will be indicated by adjacent channel selectivity difficulty along the major portion of the dial. The discrepancy may be slight, yet sufficient to cause the trouble.

2. Interfering Station Is Of A Frequency Equal To That Of The Desired Station Plus or Minus Twice The Value Of The Intermediate Frequency Used In The Receiver. This is a case of image frequency trouble. The contributing causes may be:

a. Incorrect location of the aerial lead in the receiver. Keep away from the mixer tube circuit.
b. Excessive signal strength of the interfering station. Reduce aerial length.
c. Check shielding of the RF coils.
d. The "image frequency" suppressor circuits are either detuned or defective.
e. Check trimmers of pre-selector RF circuits.

3. Interfering Station Is Of A Frequency Equal To That Of The Desired Station Plus Or Minus The Intermediate Frequency. This is a case of heterodyning between the stations themselves because both are present in the mixer system and produce the desired IF beat. The modulation in the loud speaker may be that of one or both stations. Items to be checked are:

a. Incorrect location of aerial lead in proximity to the mixer system. Also excessive signed strength.
b. Excessive strength of the interfering station.
c. Check RF trimmers.
d. Possible coupling between RF and mixer coils. Check shields.

4. Interfering Station Appears During Lapse of Speech Or Music From Desired Station Without Any Change Of Dial Setting. (Reception May Be Blurred At Times.) This is a case of two stations operating upon the same frequency being within the range of the receiver. Such a condition can not be attributed to any fault of the system. The only logical remedy is a reduction of the sensitivity of the receiver so that it would respond to only the more powerful of the two stations.

5. One Station Interferes When The Receiver Is Adjusted To A Frequency Approximating That Of The Interfering Station. Such a condition is encountered in

certain localities where one station is extremely powerful and finds its way into the receiver no matter how accurate the alignment of the circuit. The only posible remedy is a reduction of the pickup. See this classification in Section 8. Also check RF circuit shielding.

6. Heterodyne Whistle At 650 KC in 130 KC IF Peak Receivers. See listing under symptom number 7.

7. Heterodyne Whistle At 700, 875 or 1400 KC in 175 KC IF Peak Receivers. Such a condition is due to heterodyning between harmonics of the peak frequency and the signals at the stated frequencies. Check the following.

a. See Harmonics, Section 2.
b. Check the RF choke and bypass condensers in the demodulator tube plate circuit.
c. Check shielding of IF transformers.
d. Check position of aerial lead. It should be far removed from the units in the demodulator grid and plate circuits.
e. Excessive signal strength or volume control adjustment.

8. Heterodyne Whistle Upon 712, 890 and 1424 KC in 178 KC IF Peak Receivers. See listings under symptom number 7.

9. Heterodyne Whistle Upon 780, 1040 and 1300 KC in 260 KC IF Peak Receivers. See items listed under symptom number 7.

10. Heterodyne Whistle Upon 786, 1048 and 1310 KC in 262 KC IF Peak Receivers. See items listed under symptom number 7.

11. Heterodyne Whistle Present When a Station Is Being Received And The Signals Are Periodically Or Constantly Blurred. Such a condition is caused by the fact that the receiver is sufficiently sensitive to respond to two signals of approximately the same frequency being transmitted by two widely separated stations. There is no real remedy as far as the receiver is concerned. A posible remedy is the reduction of the receiver sensitivity

to the point where the heterodyne whistle is of negligible intensity. Such a condition may exist when a weak station heterodynes a strong station. By reducing the sensitivity, the intensity of the heterodyne signal is greatly decreased.

12. 1500 to 1450 KC Signal Present When The Receiver Is Tuned To A Station Between 550 and 570 KC with 175 KC Peak. Such a condition is created by two effects. The phenomenon is due to beats between a harmonic of the oscillator output and the interfering signal, also to the presence of the interfering station in the mixer system. Check the following:

a. Location of the aerial in proximity to the mixer or to the demodulator tube grid or plate.
b. Excessive pick up of the interfering station. Reduce pickup.
c. Check harmonic suppressor resistors and condenser in oscillator system.
d. Check shielding of oscillator and mixer systems.

13. Long Wave Station Interference. This condition may be due to the proximity of the powerful long wave station. Also to undesired signal input into the mixer or intermediate amplifier circuit.

a. Check aerial length and position.
b. Check shielding of RF amplifier coils and tube leads.
c. Check shielding and grounds to shields of IF transformers.
d. Be certain that aerial or ground lead are removed from mixer system and IF system.
e. Keep power leads removed from mixer and IF systems.
f. Use power line input capacity filter.

14. Heterodyne Whistle As Each Station Is Tuned In. Such a condition may be due to imperfect adjustment of the neutralizing systems if they are used in the receiver or to those items which will tend to cause an oscillatory state in the RF and IF amplifiers. This does not include excessive tube voltages in as much as such a condition is

determinable when the tube voltage test is made. Check for:

a. Incorrectly adjusted RF neutralizing condensers or IF neutralizing condensers if and when used.
b. Open grounds at the shields and shield contacts.
c. Poor contact at RF, Mixer, IF and demodulator screen, control grid and plate bypass condensers.
c. Open RF, mixer, IF, and demodulator screen grid and plate bypass condensers.
d. Incorrect location of control grid leads in RF, mixer, IF stages.
e. Shorted grid filter resistances in RF or IF stages.
f. Parasitic oscillations generated by the oscillator tube. Remove resistor from oscillator grid circuit. (Try to use valve approximating 2000-3000 ohms as the cathode bias resistor in '27 oscillator circuits.)

15. Receiver Operative Over Only A Portion Of The Tuning Dial (Single Control Superhet). In the majority of cases such a condition is due to failure of the oscillator to function as such over the dead part of the dial and to incorrect alignment. Check the following:

a. Shorted turns in the oscillator tube plate winding or tickler coil.
b. Oscillator trimmer condenser out of alignment.
c. Shorted turns in autodyne-mixer tube plate coil.
d. Undesired resistance (poor contact) in oscillator tube or autodyne tube grid coil.
e. Imperfect alignment of RF trimmers. (This condition may be experienced only when the RF tuning condensers have individual trimmers for various frequency bands. If one or two trimmers are used, a discrepancy in the trimmer adjustment will as a rule result in general low volume output.
f. Possible leak or short circuit between tuning condenser plates when the dial is set to a certain position, that is, where the receiver becomes inoperative.
g. Defective resistor or condenser in oscillator circuit.

16. Station May Be Tuned In At Two Points Upon The Tuning Dial. (Single Control Superhet.) As a rule this is due to incorrect tracking of the oscillator tuning con-

denser. Sometimes excessive power of transmitter. Check the following:

a. Check oscillator trimmer adjustment.
b. Check RF tuning condenser trimmers.
c. Check mixer circuit (also autodyne) tuning condensers trimmers.
d. Check compensating condenser adjustment in receivers which have such condensers in RF systems.
e. Check location of aerial leads. Keep away from RF and mixer circuit coils.

17. Acoustic Howl. Such a condition is created by vibration of the tube elements. Check for:

a. Microphonic tube.
b. Excessive vibration of the receiver cabinet.
c. Imperfect mounting of the chassis. (Shipping blocks not removed.)
d. Speaker directed towards tubes.

18. Audio Howl On Loud Stations. This condition is attributable to critical adjustment of neutralized circuits and operation of tubes at almost the oscillating point. Look for:

a. Incorrectly adjusted neutralizing condensers.
b. Open screen, plate and cathode bypass condensers.
c. Poor ground contacts.

19. Dead Receiver. (All Operating voltages normal). There are many causes for such a condition. In view of the fact that the trouble may be located in any part of the receiver it may be best if we apply the process of elimination in order to minimize the amount of work required to localize the fault. Accordingly we shall divide the modern super into two major sections. One section includes all the units between the aerial and the output of the demodulator tube and the other section includes the audio frequency amplifier inclusive of the coupling unit between the demodulator and the first audio tube and also the speaker system.

Test 1. The first step is to determine whether the fault is local to the first or the second sections as outlined. To do this we shall check the audio amplifier and speaker.

We start with this system because it enables a rapid check and permits the use of the output meter, thus obviating the need for plate circuit break-in adapters. To check the audio amplifier and speaker, connect the output meter across the terminals of the voice coil, leaving the voice coil connections to the secondary of the output transformer as used for regular reproduction.

Then remove the lead from the control grid of the demodulator tube, that is, the lead from the last IF transformer to the control grid of the demodulator tube. Connect the "A" lead from the test oscillator to the control grid of the demodulator and the "G" lead to the chasis of the receiver or to the cathode of the demodulator. The connections named are applicable to demodulator tubes simultaneously used as automatic volume control tubes. Adjust the test oscillator to about half the maximum output. Adjust the oscillator so that it is generating a modulated wave. If the audio amplifier is in good condition, a fairly strong signal will be audible through the speaker As a matter of fact an indication may be visible upon the output meter. Vary the test oscillator attenuator or volume control and note the change in signal intensity of the speaker sound output. If the audio amplifier appears normal, assume the defect is in the first section of receiver.

However, if no sound is audible through the speaker, disconnect the voice coil from the output meter and the secondary of the output transformer and connect the output meter across the secondary of the output transformer. Advance the oscillator output to maximum. If an indication is obtained upon the output meter, the trouble has been localized as being in the speaker voice coil. If no indication is obtained, then shift the connections of the output meter across the primary of the output transformer. Information covering the use of the output meter is given in section 6. If an indication is obtained when the output meter is in this condition, the trouble has been

localized as being in the secondary circuit of the output transformer inclusive of the voice coil. Check for:

a. Grounded secondary winding.
b. Open secondary winding.

If no indication is obtained it is necessary to check the continuity of the various units in the grid and plate circuits of the audio tubes, looking for shorts rather than opens, because an open will interfere with the application of the tube operating potentials and we have assumed that the operating potentials are normal. The sole exception to this is an open blocking condenser in resistance-capacity and inductance-capacity and auto-transformer type audio amplifiers.

The possible short circuits in such system may be:

a. Shorted AF transformer primary or secondary windings inclusive of those units which are connected in shunt with the primary or secondary windings.
b. Shorted plate and grid coupling resistors.
c. Open blocking condenser in parallel feed circuits.
d. Open AF transformer primary in parallel feed audio systems.

Test 2. If the audio amplifier is normal, the trouble has been localized as being in the first section of the receiver. The next step is to check the IF amplifier. The output meter remains connected across the speaker voice coil-secondary of the output transformer. The test oscillator is assumed to be capable of generating the required band of IF frequencies. The "A" lead from the test oscillator now is connected to the control grid of the mixer (1st detector) tube, of course after the regular lead to that tube element has been removed. The "G" terminal of the test oscillator remains connected to the chassis. The lead from the last IF transformer to the control grid of the demodulator is replaced. If the IF frequency is known, the test oscillator is adjusted to that value and if the IF amplifier is in normal condition, a very strong signal will be heard in the speaker and an indication will be visible upon the out-

put meter. Try varying the test oscillator tuning condenser and note that the intensity of the signal varies in accordance with the tuning. Naturally the maximum signal will be heard when the oscillator frequency adjustment resonates with the peak adjustment of the IF system.

If no signal is heard through the speaker the trouble has been localized as being in the IF amplifier. Once again it is a matter of hunting for short circuits rather than open circuits because normal tube operating potentials prove that the circuits are closed. Again the exception is an open in the link circuit in three winding IF transformers as shown in figure 34 or an open in the blocking condenser in circuits such as illustrated in figure 35. Check for:

a. Short circuited IF transformer primary or secondary.
b. Short circuited IF tuning condensers.
c. Short circuit between grid and ground of IF tube.
d. Shorted turns in IF transformer primary or secondary, thus interfering with the tuning. (In this connection it might be well to state that with either the primary or secondary of an IF transformer tuned to the required peak frequency, a signal of the peak frequency will pass through the system no matter how badly off resonance the other winding of the same transformer. Of course the signal will be weak, but the system will not be dead.)

Test 3. If the IF amplifier is normal the trouble has been localized as being in either the RF, mixer or oscillator circuits. To check the oscillator proceed as follows: Replace the regular lead to the mixer tube control grid after having removed the lead from the "A" terminal of the test oscillator. Then remove the receiver oscillator tube.

The "G" lead of the test oscillator remains connected to the chassis or ground of the receiver. Set the receiver tuning dial to the frequency of a broadcasting station known to be in operation. Then connect the "A" lead

from the test oscillator to the control grid lead or to the grid lead of the receiver oscillator circuit. A voltage fed into this lead will pass into the mixer circuit just as if it were being generated by the local oscillator in the receiver. Adjust the test oscillator so that the signal being generated is not modulated. (Because of the utility of a test such as that outlined, there is every reason for the design of test oscillator operated from batteries. Test oscillators operated from A.C. lines do not permit such tests.)

Tune the test oscillator so that either the fundamental or the harmonic of one of the fundamentals becomes the beating frequency. Adjust the test oscillator for maximum output. If the generated signal lies within the broadcast band, say between 1500 and 550 KC, ordinary care will be required in the tuning. If however the fundamental frequency generated by the test oscillator lies within the IF band and the beating signal is a harmonic of one of these fundamentals, care will have to be exercised in the tuning. If the frequency output range of the oscillator covers the IF band, then try selecting a fundamental which will have as its 3rd harmonic, the frequency desired.

The test oscillator now is used as if it were the oscillator in the receiver and the RF and oscillator were available with separate controls. If the broadcast signal is tuned in in normal fashion the trouble has been localized in the receiver oscillator system inclusive of the coupling between the oscillator and the mixer tube.

If the receiver employs the second harmonic system with the autodyne oscillator, the oscillator tube must remain in the receiver and test oscillator output is connected across the grid and filament circuit, with a series condenser of say .01 mfd in the "A" lead to the grid of the combination tube. The same is true of the ordinary autodyne receiver. As to the adjustment of the test os-

cillator frequency for testing second harmonic systems, the regular beating signal equal to the broadcast carrier plus the IF signal, must be produced. The same is true in the case of the autodyne systems.

The possible troubles (with normal tube operating potentials) which will cause failure of the oscillator systems are:

1. In Second Harmonic systems.
   a. Shorted second harmonic circuit coil or condenser. Shorted turns in coil.
   b. Open second harmonic circuit condenser.
   c. Shorted plate winding.
   d. Shorted RF winding or open RF tuning condenser. Also shorted RF tuning condenser in mixer tube circuit.
2. In Autodyne systems.
   a. Input tuned circuit not tracking properly. Shorted RF coil in mixer or shorted turns in coil.
   c. Open tuning condenser.
   d. Shorted plate winding.
3. In conventional systems.
   a. Defective harmonic suppressor resistors.
   b. Shorted oscillator coils. Also shorted tuning condensers.
   c. Shorted coupling coils. Also open coupling condenser.

Test 4. If the test with the external oscillator is not productive of any definite result, a check of the complete RF system is desired. Here too it is a matter of shorted windings rather than open windings. Possible defects are:

   a. Shorted RF transformer primaries or secondaries.
   b. Completely unbalanced pre-selector circuits.
   c. Open pre-selector tuned circuits other than those located immediately in the first RF tube grid circuit.
   d. Shorted resistor across aerial-ground winding.
   e. Short circuited RF tuning condensers. (We do not include open RF tuning condensers because if singular in number, it will not interfere with the passage of some signals which will remove the receiver from the "dead" classification.)

20. Weak Signals. The cause for weak signals are very similar to those which will cause a dead receiver, assuming

of course that the tube operating potentials are normal. If as previously stated, the tube voltage test shows a discrepancy, the first test is to determine why there is a deviation from the normal voltage and current ratings.

The process of elimination is like that applied for the "Dead Receiver", symptom number 19. In addition:

a. Check for incorrect RF, Oscillator, Mixer or IF trimmer alignment.
b. Check for poor contacts in RF, Mixer, Oscillator or IF coils and tuning condensers.
c. Defective colume control tube. Try interchanging volume control tube with another of like type.
d. Defective volume control tube circuit.
e. Poor aerial or ground and shield aerial.

Generally speaking the conditions which will cause weak signals will also cause distortion. In view of the fact that any one of a number of different defects will produce similar symptoms, there is no method of selecting the cause without a complete analysis of the receiver, such as outlined in connection with the "dead receiver". Recognizing that distortion is a condition related to audible sounds, testing by means of the output meter is unsatisfactory. A reproducing unit must be used. This means that if the speaker is defective it must be repaired so as to enable its use for further testing.

However, the output meter can be used to align the various trimmer condensers if a local test oscillator is used as the signal generator. As to a check for quality of reproduction, the loud speaker must be used. It might be well to mention that an off resonance condition in the RF system, oscillator, mixer or IF amplifier will cause distorted reproduction.

An additional item to be remembered during the search for defects which produce low output volume, is excessive neutralization in the form of incorrect adjustment of neutralizing and compensating condensers in RF and IF amplifiers.

21. Weak Signals And Distortion Over A Part Of The Tuning Dial. This is a sure sign of incorrect trimmer condenser alignment, usually in the RF, mixed or oscillator circuit. Since the quality is good over a part of the dial, the IF transformers must be correctly tuned and the only circuits which may be at fault are those being continuously tuned.

22. Distortion And Weak Signals. See explanation of causes for Weak Signals, symptom 20.

23. Distortion And Strong Signals. As a rule this condition is due to tube overloading or to speaker troubles. However we must also recognize that such a condition may be due to the fact that the various tubes are operating close to the oscillating condition due to open bypass condensers in the screen, cathode and plate circuits. In some cases, audio frequency tube overloading will cause rasping and blasting sounds in the speaker, which symptom would tend to create the impression that the fault lies in the speaker. A means of checking is to reduce the volume and note the difference. For further data see "Distortion" symptom 31 in this section.

24. Oscillator Drift. (The need for Frequent retuning.) This condition may be caused by any one of several defects. It is manifest as frequent need for retuning of the receiver and the actual condition is a variation of the frequency of the oscillations being generated by the oscillator tube.

It might be well to mention at this time that the frequency of oscillations generated by an oscillator tube of conventional type is controlled in a measure by the operating potentials. A number of tests upon receivers have shown the following reasons for oscillator frequency drift. Unfortunately it is impossible to definitely state that any one of the following may be causing the condition in a receiver, but these have been found to be the causes in a large number of receivers afflicted in this fashion.

a. Defective bypass condensers connected across the resistances which limit the plate voltage applied to the oscillator. By defective in this instance we do not mean a short circuit. Instead high resistance connections to the leaves of the condenser foil and high resistance soldered joints.
b. Moisture absorption by the dielectric of the fixed condenser used in the tuned circuit and also in the grid circuit.
c. Imperfect ground connection to the tuning condenser rotor plates and to the shield if one is used to cover the oscillator tube.
d. Defective resistances, particularly those in the grid circuit. The resistors used between the oscillator plate and the power pack, if not perfect will cause voltage variations and a drift in the frequency being generated.
e. Coupling between the grid and plate leads of the oscillator tube and the tuned circuits of the RF or mixer system.
f. Variation of the spacing between the tube element due to the heat developed by the incandescent heater and cathode.

25. Need For Frequent Readjustment Of The IF Trimmers. We list this item separately because such a condition will arouse the question concerning the cause. Generally it is due to a poor dielectric in the IF trimmer and to a worn adjusting screw thread. In some cases it is due to moisture absorption on the part of the IF trimmer condenser base. The only remedy is replacement of the trimmer condenser if possible. If not, then replace the entire transformer.

26. Parasitic Oscillations. This condition is experienced in connection with the oscillator tube. The trouble appears in the form of a continuous whistle. An examination of the RF, IF and AF stages shows them to be functioning in normal manner, yet the howl persists. It may be caused by excessive plate voltage or insufficient bias voltage. Some oscillator circuits employ a 2000 ohm resistor in the grid circuit and no grid bias resistor. Remove the resistor from the grid circuit and locate

it in the cathode lead, using the resistor as a bias unit.

27. Gassy Tubes. Gassy tubes cause erratic operation. The presence of sufficient gas in a tube will render it inoperative. The presence of gas is at times indicated by grid current without signal input and by abnormal plate current, sometimes by noisy operation. A sign of a gassy condition is a gradual increase in plate current after a few minutes of operation.

28. Gassy Automatic Volume Control Tubes. A gassy automatic volume control tube causes a condition equivalent to the application of a high grid bias to the variable bias controlled amplifier tubes. The gas in the AVC tube increases the plate current. Whichever type of AVC structure is used, a high plate current in the AVC tube causes the development of a high negative bias which is applied to the bias controlled amplifier tubes. The net result is the reduction of the receiver sensitivity. If the bias is of sufficient value, the receiver will become inoperative because the amplifier tube plate current is reduced to zero.

29. Deactivated Automatic Volume Control Tubes. If the AVC tube does not have sufficient emission, automatic volume control will not be achieved. The receiver will operate with maximum sensitivity at all times, and manual volume control (if available) will have to be used.

30. Hum And Noise. Hum as a rule is associated with some defect in the system. However, you must also bear in mind that hum may be present in a system because of some defect in a tube, although the measured characteristics of the tube are normal in every respect. In view of the fact that an elaborate test is required to verify such a condition, the logical form of test is replacement. Another condition which may be encountered with tubes in general and screen grid tubes in particular, is a hissing and sometimes sputtering sound. Once again the tube characteristics may be normal, yet the tube will be found

to be noisy. The only remedy is replacement.

As to other conditions productive of hum, check for the following:

a. Incorrect filament centre tap.
b. Coupling between grid or plate leads and AC filament circuit.
c. Picked up from power line by speaker or amplifier.
d. Open filter or bypass condenser.
e. Reversed plug in AC socket.
f. Open half of filament shunt resistance.
g. Aerial lead close to power line.
h. Shorted filter choke.
i. Shorted hum filter resistor in demodulator plate circuit.
j. Open AC line to ground condenser.
k. Hum adjuster improperly adjusted.
l. Shorted grid filter resistors.
m. Open parallel resonant circuit in filter.
n. Wrong frequency AC supply.
o. Defective rectifier tube.
p. Poor contact and high restance joints to bypass condensers and filter condensers.
q. Defective resistors and overloaded resisters, wire wound and otherwise.
r. Photograph switch incorrectly set.
s. Loose power transformer laminations or winding.
t. Loose audio transformer cores or windings.
u. Loose dielectric in fixed condensers.

Noise is quite a problem with a highly sensitive receiver. So much so that tube noises, normally unnoted because of low gain, become quite bothersome. One of the major causes for a "hiss" background in a high gain receiver of the system is operation too close to the point of oscillation. In the superhet, the RF, mixer, IF, demodulator and AF stages are possible points of trouble. The "hiss" background becomes more pronounced when a station is tuned in and the fact that such a condition does take place is a sign of some imperfection in the receiver. Hence noise of this type is allied with the items which will cause excessive regeneration in the system.

Noise may be due to resistor which was overloaded during the time that some other unit in the receiver failed or went bad. The repair or replacement of the defective unit restored the normal operating voltages, but the effect of the temporary overload applied to the other resistor may and very often does remain. Solid dielectric blocking condensers used in resistance-capacity audio amplifiers must be considered as likely sources of noise. Very often a leaky condtion will arise, yet a routine DC leakage test will not show the trouble. This may sound strange but it is true nevertheless. The only means of determining whether or not the condenser is defective is to replace it.

Determining the location of noisy elements is one of the most difficult of all problems because in many instances electrical continuity is not disturbed. A very concrete example of such an instance is a defective transformer winding, wherein the two ends of the separate layers come in momentary contact or the insulation between two adjacent turns is imperfect. Electrical continuity tests will not bring such troubles to light and replacement is the only sure test. Further data relative to the isolation of the system responsible for noise in a receiver, when the defective unit is within the receivers is discussed elsewhere in this book.

31. Distortion. Supplementary to the distortion due to an off resonance condition, an imperfect tone control system and a speaker voice coil out of adjustment, the following items related to tubes, should be checked:

a. Tube oscillating.
b. Gassy tube.
c. Low or excessive screen voltage.
d. Low heater voltage.
e. Low or high grid bias.
f. Low or high plate voltage.

In each case, normally indicated by the routine set analyzer test, it shall be necessary to determine why these voltages are low or high and depart from the normal

rated value. Items related to tube operation but not necessarily of the kind which will influence the operating voltages, yet which will cause distortion are:

g. Open bypass condensers in the grid, cathode, screen or plate circuits.
h. Incorrect shunt capacities across audio coupling units.
i. Incorrect or defective resistances across audio coupling units.

32. Hot and Cold Tube In Parallel Or Push-Pull Combination. Such a condition is due to non-operation of one of the tubes. The tube which is running "cold" is defective and results in an overload of the other tube, hence overheating of the good tube.

33. Rectifier Tube Does Not Glow. Check the following:

a. AC line switch open.
b. AC power cable open.
c. AC line fuse open or making poor contact.
d. Power transformer primary open.

33. AC Line Fuse Blows When Set Is Turned On. Check the following:

a. Short circuit, noise filter across AC power line.
b. Shorted power transformer primary.
c. Rectifier tube shorted.
d. Power transformer secondary winding shorted.
e. Power pack filter grounded.
f. Output tube plate circuit grounded.
g. Power pack filter condenser shorted.

34. No Plate Voltages. The trouble may be in the power pack connections thereto or in the receiver proper. Check the following:

a. All items listed under symptom 33.
b. Defective rectifier, or poor contact in rectifier socket.
c. Open rectifier filament or plate winding.
d. Open filter choke, or shorted filter choke.
e. Shorted filter condenser or voltage divider bypass condenser.
f. Shorted bypass condenser in tube plate circuit.
g. Open coupling in tube plate circuit.
h. Open D minus lead in tube circuit.
i. Speaker field open or grounded.

j. Centre tap of power transformer plate winding open.
k. Speaker plug disconnected.
l. Open voltage reducing resistance in plate circuit.
m. Open hum or filter resistance in plate circuit.

35. No Heater or Filament Voltage. The trouble may be located in the power pack or in the receiver proper. Check for the following:

a. Open filament winding.
b. Open primary of power transformer if separate filament transformer is used.
c. Shorted filament winding.
d. Shorted hum suppressor.
e. Open filament circuit.
f. Shorted pilot light or socket.

36. No Grid Voltage. The trouble may be either in the power pack or in the receiver proper. Check for the following:

a. Open coupling unit in grid circuit.
b. Open cathode.
c. Open B minus lead in tube circuit.
d. Open grid filter resistance.
e. Shorted grid bias resistance.
f. Shorted volume control in grid circuit.
g. Open volume control resistance in grid circuit.
h. Deactivated tube.
i. Oscillator coupling coil open.
j. Ground side of oscillator coil open.
k. Open tap on voltage divider bias resistance.
l. Deactivated AVC tube.
m. Leak in coupling unit.

37. No Screen Grid Voltage. Check for the following;

a. Open volume control tap.
b. Open lead in screen grid circuit.
c. Shorted screen grid resistor bypass condenser.

High Operating Voltages. High values are due to short circuits in those units which are used as coupling unit or as voltage reducing units in the various circuits. The possible exception is the high control grid bias which is due to a short circuit across a bleeder resisted connected between the screen grid and cathode or between the plate

circuit and cathode. In contrast to shorted condensers which cause "no" voltage, an open condenser will have no effect upon the operating voltage, unless is the input filter condenser, in which case there will be a tendency to reduce the eliminator output voltages, therefore the operating voltages.

38. Rasping Sounds From Speaker. If the trouble is not due to tube overloading, check the following:

a. Speaker voice coil loose.
b. Speaker voice coil out of adjustment.
c. Speaker diaphragm torn.
d. Speaker voice coil strikes pot magnet.
e. Foreign particles between voice coil and pot magnet pole.
f. Speaker diaphragm loose on outer support.
g. Intermittent grounding of voice coil.

39. Sympathetic Audio Vibrations. As a rule such sounds are caused by loose units, screws, cans, etc., set into vibration by the speaker. At certain frequencies, these loose parts will vibrate in sympathy with the speaker diaphragm, giving forth sounds foreign and of interfering nature with respect to the normal speech and music issuing from the speaker.

Section 5

PRELIMINARY SERVICE PROCEDURE

The writer has received numerous letters requesting information concerning the intermediate frequency adjustment of the IF amplifiers used in superhets. If a test oscillator (calibrated) capable of generating a modulated wave over the 130 KC to 270 KC band is available, it becomes a very simple matter to determine the IF peak of a receiver. The only time when the method to be outlined is not applicable is in the event of a short circuited IF primary or secondary or when every IF condenser has been incorrectly adjusted and the IF transformers are tuned to different frequencies. If one IF transformer tuning condenser is out of alignment it will not interfere with the determination, sufficient signal will pass through the system to enable an accurate decision.

An output meter is not required. The speaker can be used, providing of course that the system is not dead. Connect the output of the test oscillator adjusted for the IF band to the control grid lead of the mixer (1st detector) tube and the chassis of the receiver. Starting at the highest intermediate frequency adjustment of the test oscillator tune slowly towards the low end of the test oscillator frequency scale. No doubt this would be towards the higher numbers upon the test oscillator tuning dial. You may find two points at which a signal becomes audible in the speaker. Whether you find two or just one depends upon the IF peak used in the receiver and the frequency range of the oscillator. There is even an exception to this, namely the case of a few kit receivers which employ a 460 or 480 KC peak. If you are checking a commercial broadcast receiver with a peak frequency between 130

and 265 KC, and the test oscillator has a 130 to 270 KC range, two points will be found for receivers utilizing peak frequencies between 260 and 270 KC.

Starting at the uppermost end of the IF band of the test oscillator, a signal may be found between 260 and 265 KC. and another signal for the same receiver may be found around 130 or 131 KC. The first signal is the peak adjustment of the receiver and the second signal is the 2nd harmonic of the 130 or 131 KC signal which also equals the peak adjustment of the 260 or 262 KC peaked receivers. If the first signal is heard between 170 and 180 KC, there will be no other signal through the system. Note the tuning adjustment of the test oscillator when the signal is heard with greatest strength and then determine the frequency for this setting. The answer is the peak adjustment of the IF system in the receiver.

It is possible that the receiver utilizes a flat top tuned IF transformer in which case the signal will appear strong over a band of perhaps 4 or 6 KC around a certain frequency setting. In this case the peak adjustment rating of the IF system is equal to the frequency setting midway between the two limits where the signal is strong.

In the case of the superhets which use a 460 or 480 KC peak IF system, three points of response may be found. In each case it is due to a harmonic of the fundamental IF being generated by the test oscillator. For the 460 KC peaked system, these signals will appear first at 230 KC setting of the oscillator and then at about 153.3 KC. For the 480 KC peak signal the first signal will appear at about 240 KC and the second at about the 160 KC of the test oscillator.

The band pass adjustment of the IF system in the receiver can be noted by observing the range of response sides of the peak. A maximum of about 4 KC each side of the peak should give response. More than this means that the IF system will cover more than the 5 KC sidebands normally present in the modulated signal passed into the IF system and trouble may be experienced from lack of adjacent channel selectivity in the RF system.

Section 6

APPLICATION OF RF AND IF OSCILLATORS

We shall take for granted during the explanation of the application of RF and IF oscillators that you are familiar with such units.

We have made reference to the fact that an oscillator calibrated in intermediate frequencies is suitable for use when aligning RF circuits. This application is made possible by the fact that the average oscillator is very rich in harmonics so much so that harmonics up to the 15th may be employed. This is true over the entire range from about 90 to 260 KC. Of course some oscillators do not extend as low as 90 KC but this in no way impairs the use of the harmonics present in the output.

As far as actual use is concerned and ease of alignment, we have found that battery operation, that is the use of battery voltage supply, is by far the best. The tuning of the received signal is sufficiently sharp and the modulation signal is very defined.

The Adjustment Of RF And Pre-selector Circuits

Before starting upon this description, it might be well to make brief mention of some facts pertaining to RF trimmer condensers. As a rule RF trimmers are located adjacent to the various tuning condenser sections, usually mounted upon one of the dielectric side supports. The

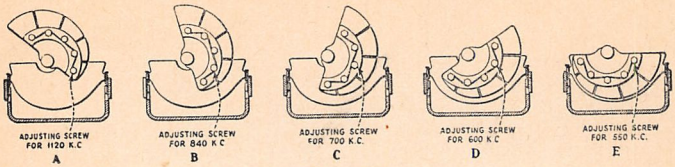


Fig. 45
(Courtesy RCA—Victor Co.)

number of such trimmers used for each tuned section depends entirely upon the design of the receiver. In the majority of cases, each tuned section has two trimmers, a high and a low frequency adjustment units. The high frequency trimmer is as a rule intended to line up the section at between 1400 and 1200 KC, with the former figure being most popular. The low frequency trimmer is intended for adjustment at between 600 and 650 KC, with the former frequency being most popular. Where a single unit is used, adjustment is usually at the high end of the frequency spectrum.

Another type of trimmer arrangement consists of the use of a slotted end plate upon the tuning condensers, one such slotted plate for each tuning section. An example of such a condenser appears in figure 45. This illustration is taken from an RCA service manual and shows the five slots upon the end plate of the tuning condenser and the screw adjustments for the various line up frequencies. Each screw controls one plate of the slotted group. As is evident the line up adjustment is made at five different frequencies.

Certain things must be borne in mind during the alignment of trimmer condensers. These are: first, the tube to be used in the socket must be in place. Second, if a tube shield is used over the tube, it too must be in place and in firm contact with the shield base, thus assuring a good ground. Third, the operating voltage applied to the tubes must be that used when the receiver is placed into every-

day operation. Fourth, all connecting leads must be in place as found when the receiver is used for normal broadcast reception. All of these items influence the adjustment of the trimmer. This is so because each of these items represent capacity across the RF coil and the trimmer adjustment is governed by the total capacity across the coil or RF transformer. The fifth, and by far not the least important consideration is that all trimmer adjustments be made upon a wood top table rather than a metal top table. One or more of the transformers utilized in the receiver are located upon the underside of the chassis and may be influenced by the metal top, be it insulated, coated, or otherwise. Such proximity to metal alters the inductance, therefore the capacity adjustment.

Referring once more to the test oscillator, we have the two types mentioned; namely, that which produces a fundamental frequency within the broadcast band and that which produces a fundamental within the IF band. The former we shall designate as an RF oscillator and the latter as a combination RF-IF oscillator. If the unit used is of the former type, there is no need for an explanation of the frequency adjustment. However, in the combination RF-IF oscillator the frequency adjustment for broadcast carrier frequency will actually be an intermediate frequency. The test oscillator is producing the intermediate frequency signal but at the same time is also generating harmonics of this signal. The selection of whatever harmonic is desired is made by the tuning of the receiver circuits. Thus if such an oscillator is adjusted to generate a fundamental of 180 KC, it is also generating the 360 KC, 540 KC, 720 KC, 1080 KC, 1260 KC, 1440 KC, etc., these being the harmonics from and including the 2nd to the 8th. By tuning the receiver RF condensers to any one of these desired frequencies, that harmonic becomes the test signal and tunable by the receiver. Thus with a combination RF-IF oscillator with a range of from 90 to

260 KC, and by utilizing the harmonic range up to the 8th, we can secure test frequencies from 90 KC to 2080 KC.

Harmonics are also generated by the RF oscillator, but since we can secure the required frequency by the fundamental adjustment there is no need of utilizing harmonics, despite the fact that the 2nd harmonic of 600 KC is 1200 KC and available when the oscillator is adjusted to a fundamental of 600 KC.

To align the receiver, it is necessary to "pull" the chassis, remove it from the cabinet. Of course all power circuits remain intact so as to allow use of the receiver. The speaker remains connected. After the chassis has been removed from the cabinet, it is necessary to arrange some means whereby one can judge the frequency adjustment of the condensers according to the dial indications. In other words a pointer must be arranged. In some instances, the complete indicating assembly remains intact when the chassis is removed, but in other cases the pointers are part of the escutcheon plate upon the front of the cabinet. The location of the temporary pointer must be such that the dial settings correspond EXACTLY with the settings when the chassis is placed within the cabinet. A safe arrangement in the event that the pointer is a part of the escutcheon plate is to fully mesh the condenser with the chassis in the cabinet and make a mark upon the dial showing the location of the pointer for this setting of the condenser. This is a safer arrangement than making such a mark when the condenser plates are adjusted for some frequency between minimum and maximum. The temporary pointer can be a piece of No. 18 or No. 20 wire fastened to the chassis and bent and placed in such fashion that one end is parallel to the horizontal lines upon the drum dial.

There exists a difference of opinion relative to the most practical method of alignment, that is whether to

first align the IF stages and then the RF or to choose the RF system first. It is logical to expect that the IF stages should be aligned first since the tubes in this system can be utilized as amplifiers to facilitate the alignment of the RF system. Furthermore, it is essential that the IF system be correctly tuned in order to enable maximum deflection upon the output meter, However, if we look at the problem from another angle, it is doubtful if (unless the receiver has been tampered with) both the RF and IF stages get out of alignment at the same time. Furthermore even a misaligned IF system, unless the condensers are entirely shorted, will pass a signal through to allow the adjustment of the RF system. Since the RF amplifier represents the beginning of the complete receiver system, and since alignment of the IF stages ahead of the RF means nothing more than greater output indications, we feel justified in starting with the RF system.

As previously mentioned all receivers are not intended for RF alignment at like frequencies. What is to follow does not apply to the adjustment of the Atwater Kent RF systems in supers utilizing the double spot circuit. This shall receive special mention. The most popular "high" alignment frequency is 1400 KC.

With the chassis "pulled" and ready for the alignment adjustments, the test oscillator is tuned to generate a 1400 KC signal (fundamental or harmonic) and the test oscillator volume control is set at about half maximum output. Allow the test oscillator tube to reach a steady temperature. Connect the output meter across the voice coil of the speaker or across the secondary of the output transformer. It is best if the output meter is connected across the combination of the voice coil and the output transformer secondary. Such an arrangement will enable audible recognition of an oscillatory state. Adjust

the receiver volume control for about half maximum output.

Then connect the "A" terminal of the test oscillator to the aerial post of the receiver and the "G" terminal of the test oscillator to the ground post of the receiver. In some instances it might be advantageous to insert a .0001 mfd condenser in series with the lead between the "A" post of the test oscillator and the aerial terminal of the receiver. There are two methods of operation from this point on. Both will be described. The selection of either depends entirely upon the care and effort you wish to place into the alignment work and the ease with which it is possible to disconnect one of the circuits. The first method consists of adjusting the dial so that the 1400 KC mark lines up with the temporary pointer. Then adjust the various RF trimmers until maximum output is obtained. If the output meter indicator needle goes off scale, reduce the output of the test oscillator. Use an insulated screw driver for all trimmer adjustments. It is best to start operations with the trimmer nearest the mixer or most distant from the aerial circuit. The aerial trimmer when provided is used to adjust the circuit for maximum response with the aerial connected.

The second method of aligning the RF trimmers is as follows. With everything ready for the adjustment, disconnect the lead from the receiver oscillator tube grid to the stator of the oscillator condenser. Connect an external condenser of about .0005 mfd in place of the condenser in the receiver, stator to the grid lead and rotor to the chassis or according to the connection of the rotor of the oscillator condenser in the receiver. It should be understood that this external condenser is located external of the receiver. It might be well if a laboratory model, (shielded) condenser is used for this purpose. The use of such an external oscillator condenser enables adjustment of the RF trimmers independent of what may be

the condition of the receiver oscillator circuit. The receiver dial is set to the 1400 KC mark and the external oscillator is tuned for maximum signal. Then the RF trimmers are adjusted for maximum output indication.

Without disturbing the setting of the receiver dial, the external receiver oscillator condenser is disconnected and the regular condenser in the receiver is again connected into the circuit. If the oscillator within the receiver has a condenser which is to be adjusted at 1400 KC, this trimmer now is aligned for maximum output meter indication.

If the oscillator within the receiver does not have a high frequency trimmer, and the RF tuning condensers have slotted sections which may be adjusted at various frequencies, the external oscillator condenser is not disconnected. Instead, the test oscillator is adjusted to the next RF lineup frequency. Then the receiver dial is set to that frequency and the external oscillator condenser manipulated for maximum response. Then the trimmer is adjusted for maximum output meter indication.

In some instances, the receiver oscillator tuned circuit is arranged for but one trimmer adjustment, namely at about 600 KC. The use of the external oscillator is highly recommended for alignment of the receiver oscillator. This operation is carried out in the following manner:

Having completed the 1400 KC adjustment of the RF trimmers, the test oscillator is adjusted to 600 KC. The receiver dial now is set so that the 600 KC mark lines up with the temporary pointer. The external oscillator condenser now is adjusted for maximum output meter indication. Then the RF trimmers are aligned for maximum output. Without disturbing the receiver dial, the external oscillator condenser is disconnected and the oscillator condenser within the receiver is connected into the circuit. Without disturbing the dial setting the 600 KC oscillator trimmer is aligned for maximum output. Operating in this fashion removes troubles apt to occur if both

the oscillator trimmers and RF trimmers are out of alignment.

In some receivers, the RF circuits have trimmers which are adjustable at 1400 KC and the oscillator is adjustable at 600 KC. The oscillator condenser arrangement is still applicable, but in the event that it is not used, the first method of alignment as previously stated is applicable. As to the 600 KC alignment of the oscillator, set the test oscillator to 600 KC and set the tuning dial to correspond to 600 KC. Then adjust the receiver oscillator trimmer for maximum deflection. With these adjustments completed, the RF and oscillators are correctly aligned.

Adjustment of IF Transformers.

This operation follows after the RF and oscillator adjustment. Not because such alignment is always necessary but because the method of alignment represents information for present or future use. It is of course understood that if the RF and oscillator alignment or the RF alignment alone, is sufficient to restore the receiver to its required state of sensitivity, there is no need for IF alignment.

Reference to Section 3 "The IF Amplifier" states the types of systems in use and the number of IF trimmer condensers to be expected.

A modulated IF oscillator is required for alignment of the intermediate frequency transformers. Whether this oscillator is an independent unit with its own power supply or it is like the Majestic 175 KC oscillator which secures its operating potentials from the oscillator socket within the receiver and is shown in figure 46, the actual operation of the unit remains the same. For the sake of universal application we shall consider a separate oscillator as being the test unit. Any one of the commercial combination RF-IF or only IF oscillators will do.

To align intermediate frequency transformers it is necessary to "pull" the chassis. However, in this case, it it not necessary to arrange a temporary dial indicator unless you wish to do so for further testings of the receiver by tuning to a known broadcast frequency. Adjust the test oscillator to the correct intermediate frequency. The output meter is connected to the voice coil or to the secondary of the output transformer. The "G" terminal

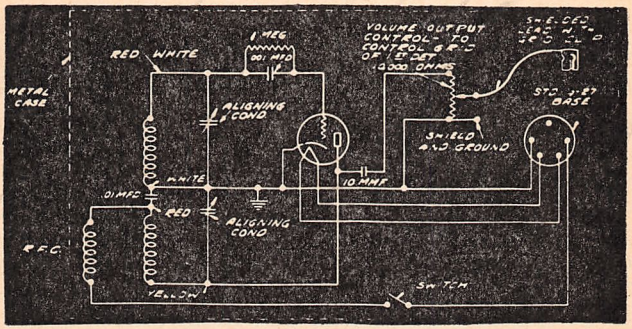


Fig. 46
Majestic 175 KC oscillator (RF windings are Majestic IF transferences)

of the test oscillator is connected to the ground post of the receiver or directly to the chassis. Make sure that the contact is firm. The IF tubes to be used in the receiver must be in their sockets. All tube shields must be in place and all connecting leads in their correct places.

If a screen grid tube is used as the mixer remove the control grid lead normally connected to the control grid cap from the control grid cap. If a type '27 tube is used as the mixer disconnect the grid lead from the grid terminal of the tube socket. It is understood that the mixer tube remains in its socket. Remove the receiver oscillator tube from its socket and if you desire to keep the receiver tube voltages fairly constant with the oscillator tube removed, connected a 20,000 ohm resistor between the plate

and cathode terminals of the oscillator tube socket. This applies to a '27 type tube. If the oscillator is of the screen grid type, connect a 100,000 ohm resistor rated at 2.5 watts between the plate and cathode terminals of the socket.

Now connect the "A" lead of the test oscillator to either the control grid cap of the screen grid mixer tube or to the grid terminal of the '27 type mixer tube socket. We are ready for the alignment. Once again two methods are available. This time the choice is involuntary. It is determined by the design of the circuit, that is, whether the IF transformers are peaked by simply resonating the primary and secondary circuits or if the IF transformers are arranged for flat top tuning. Flat top tuning of IF transformers is the subject of another part of this section, hence we shall concern ourselves with ordinary alignment.

The test oscillator is adjusted for about half the maximum output and the manual volume control in the receiver is arranged for maximum output. If a volume control tube is used see that it becomes inoperative or is removed. Removal of this tube is possible only when it is a separate tube functioning solely as an automatic volume control tube and not as a combination demodulator and automatic volume control tube. In the latter case volume control action will be secured but it will not interfere with the alignment in as much as such receivers employ a manual volume control in the audio system and sufficient gain can be had to allow a satisfactory output indication.

With the test oscillator generating the required signal, adjust the secondary circuit trimmer of the IF transformer nearest the demodulator tube, as shown upon the diagram. This would be the second IF transformer in a single stage system and the third IF transformer in a two stage IF system. Align the trimmer until the maximum indication is secured upon the output meter. Without disturbing the adjustment of the secondary circuit trim-

mer, align the primary circuit condenser (if it is of the adjustable type) of the same IF transformer until maximum output meter deflection is secured. Then repeat the alignment upon the secondary and primary circuits respectively of the other IF transformer or transformers as the case may be, working towards the mixer tube.

After all of the IF trimmers have been aligned it is good practice to recheck each one. If desired, a complete checkup can be made by removing the test oscillator connections so the mixer tube, replacing the control grid lead or resoldering the grid lead in the case of the '27 type mixer, replacing the receiver oscillator and feeding a modulated RF signal into the aerial circuit of the receiver by properly connecting the "A" and "G" terminals of the test oscillator to the aerial and ground posts of the receiver. Tune the receiver to the frequency of the test oscillator and note the output meter indication. Then carefully readjust each IF trimmer for maximum output meter indication. A test of this type is possible only when you are certain that the RF and oscillator circuits in the receiver are tracking in perfect fashion.

Flat Top Tuning Of IF Transformers.

Flat top tuning adjustments differ from the conventional peak adjustments in that the primary and secondary circuits of the IF transformer are closely coupled and a definite amount of interaction between the primary and secondary windings is desired. Furthermore the tuning of the respective circuits is such that a plus or minus frequency variation will give the same output. This means that the actual adjustment is made over a range of IF frequencies rather than at a single peak frequency.

An example of this is the following: Whereas the conventional IF transformer is peaked at say 175 KC, the flat top tuned transformer is peaked at frequencies between say 171 and 179 KC, or about 4 KC each side of the 175 KC peak setting.

In order to enable such operation it is important that the IF oscillator have a vernier adjustment whereby one can vary the IF oscillator in steps of 1 KC.

The first step is the peaking of the transformer, just as if it were to be used as a peaked transformer. (See "Adjustment of IF Transformers".) What is to follow is applicable to whatever peak frequency is used and the usual band pass considered in such flat top tuning is about 4000 cycles (4 KC) each side of the peak for the flat top. The remaining 1 KC each side of the peak is automatically secured by the resonant characteristic of the circuit. If the flat top were arranged for 5000 KC, the resistance present in the system would spread the response curve of the transformer beyond the 5 KC limits each side of the peak.

After the transformer to be adjusted for flat top tuning has been peaked, the flat top adjustment follows. This consists of slowly varying the test oscillator frequency over a band of about 8 KC with the peak frequency as the mid point. In a 175 KC peak system this test oscillator frequency band would be from 171 KC to 179 KC. Simultaneous with the variation of the test oscillator frequency is the tuning of the primary and secondary circuit trimmers until the output at the upper and lower frequency limits is the same and a variation of about 2.5 KC each side of the 175 KC adjustment of the test oscillator does not produce any change in indication upon the output meter connected to the receiver. To make such an adjustment the first time will be quite difficult but experience will enable flat top tuning at a rate as rapid as for ordinary peak tuning. Fortunately very few receivers make use of such tuning in the IF stage. An example of its application is the RCA 80 series and the equivalents in the Westinghouse, General Electric and Graybar lines.

In the event that a "local-distance" switch is used and it controls a resistance inserted into one of the IF transformer secondary circuits, this switch must be set to "distance" when adjusting the tuning of the transformers.

Adjusting Double Spot Circuit (Atwater Kent Receivers)

This system is native to the Atwater Kent receivers and is included because normal discussion of superheterodyne trimmer alignment does not include such circuits. The schematic of the system is shown in figure 23.

The adjustment of the double spot circuit requires a test oscillator (modulated) and tunable to 1500 KC with an adjustment whereby an extra strong and a normal 1500 KC signal are available. The output meter is connected across the voice coil. The output of the test oscillator is connected across the aerial and ground posts of the receiver. With the test oscillator adjusted to the normal 1500 KC signal output, the preselector trimmers are adjusted for maximum response, particularly trimmer number 3 in figure 23. Then switch the adjustment of the oscillator so that the extra strong 1500 KC signal is being secured. Now tune the receiver 1240 KC and adjust the double spot trimmer so that minimum signal is indicated upon the output meter. It is possible that a certain indication will be observed upon the output meter showing that total elimination is not secured. This is normal but care must be exercised to see that whatever the indication, it is the minimum possible by fine adjustment of the double spot circuit trimmer. Then change the test oscillator to the normal 1500 KC signal and retune the receiver to 1500 KC and readjust trimmer number 3 for maximum output indication. Then tune the receiver to 1240 KC and adjust the oscillator for the extra strong 1500 KC signal output. Now carefully readjust the double spot trimmer for minimum signal indication upon the output meter. Repeat these adjustments until further adjustment of number 3 trimmer does not increase the output of the receiver and further adjustment of the double spot circuit trimmer does not reduce the output of the receiver a 1240 KC to a greater extent.

A Special Image Frequency Suppressor System

One or two manufacturers use a special image frequency suppressor system consisting of a tap upon the coil connected into the mixer input circuit. The lead from the control grid of the tube connects to the tap upon this coil. The tuning condenser is connected across the entire coil and is resonated to the broadcast carrier frequency. The tuning condenser rotor and low end of the coil are grounded in normal fashion. The location of the tap to which is connected the control grid lead is determined by the intermediate frequency. For 175 KC the tap is said to be located at a point equal to 40 percent

of the total inductance, up from the low end of the coil. An example of this system is to be found in the late De-Forest-Crosley (Canadian) superhets and in some U. S. Radio and Television receivers. The system is used in an auto detector combination. See figure 26A.

Arranging Output And Signal Intensity Indicating Circuits

There are two practical methods of noting signal output in connection with trimmer adjustments or for comparison purposes. One is the use of the modern commercial output meter, electrical wiring diagrams of which are shown in the "Perpetual Trouble Shooter's Manual". The other is the use of a milliammeter located in the plate circuit and utilized as an indicator of the plate current change due to the application of the signal voltage. Figures 47 and 48 show the use of the commercial output meter connected across the voice coil or across the

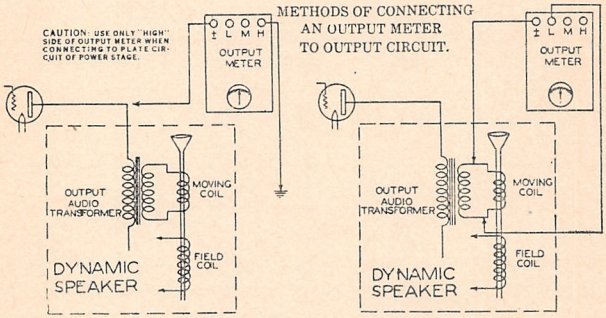

METHODS OF CONNECTING AN OUTPUT METER TO OUTPUT CIRCUIT.
CAUTION: USE ONLY "HIGH" SIDE OF OUTPUT METER WHEN CONNECTING TO PLATE CIRCUIT OF POWER STAGE.
± L M H
OUTPUT METER
OUTPUT AUDIO TRANSFORMER
MOVING COIL
FIELD COIL
DYNAMIC SPEAKER

Fig. 47 and 48
Connection of output Meters
(Courtesy Sparks—Withington)

secondary winding of the output transformer. (These diagrams are from a Sparton service manual). Note that the "high" range of the meter is used when the meter is connected across the plate terminal and ground of the

output transformer. Also that the "low" range is used when the meter is connected across the voice coil or secondary of the output transformer. It might be a good idea as a safety measure, to insert a 1 mfd fixed condenser rated at DC voltage equal to twice the output tube plate voltage between the plate lead of the output tube and the "live" terminal of the output meter.

The plate current type of indicator consists of a low range plate current meter inserted into the plate circuit of the mixer tube or into the plate circuit of the demodulator tube, depending upon the circuits being aligned. If the IF amplifier is to be used during the alignment of the RF and oscillator circuits, the plate current meter is connected into the plate circuit of the demodulator tube. For that matter, the meter may be inserted into the cathode circuits of the tubes named. The meters need not exceed 2 or 3 milliampere range. If desired a variable resistance shunt in the form of a 30 ohm rheostat can be connected across the meter to enable a variable increase of its range in the event that the plate current variation exceeds 2 or 3 mils. The meter is connected between the plate of the tube and whatever units are located in the plate circuit. If the meter is connected into the cathode circuit, it is connected in series with the cathode of the tube and the cathode circuit in the receiver. In the former case a plate circuit break-in adapter is required and in the latter case a cathode circuit break in adapter is required.

The motion of the meter pointer depends upon the signal input and the design of the grid circuit. If the demodulator is of the biased type, the meter indication will increase with signal input, being maximum for maximum signal input. The controlling factor is the carrier amplitude and not the modulation amplitude. In the grid leak-condenser system, the meter pointer will move "downward" as the signal is applied, maximum "downward" reading being secured for maximum signal input. In both cases maximum signal input is secured when the trimmer adjustment is such as to most accurately resonate the circuits with the test frequency.

In the event that commercial output meters are not available, it is possible to improvise output indicators suitable for application across the voice coil or secondary of the output transformers. One such system consists of

a 0-115 milliampere thermo galvanometer. A 10 ohm variable resistor connected across the meter can be used as a stunt to extend the range of the instrument. Another instrument suitable for work of this kind is a 10 volts AC meter.

The Adjustment of Automatic Volume Control Systems Used With Visual Tuning Meters

The combination of an automatic volume control system and a visual tuning meter is confusing at times because the gain leveling action of the automatic volume control tube interferes with the use of the visual tuning meter as a resonance indicator during testing. The adjustment of this tube during testing and actual operation depends upon the design of the automatic volume control system. In view of the fact that the usual consequence of a deactivated automatic volume control tube (excluding the diode type which also functions as a demodulator tube) is lack of volume control, the automatic volume control tube should be removed during the aligning process. If the visual tuning meter goes off scale, it should be shorted out of the circuit because the output meter will indicate the effects of the alignment. If desired, the visual indicator may be temporarily shunted by a variable resistance of about 20 ohms and this resistance set so as to afford the required current scale.

As stated Section 3, the volume control in many systems is equipped with a variable bias resistance whereby the minimum level is definitely set. Adjustment of this resistance automatically varies the minimum bias applied to either the RF or IF tube or both tubes. This action takes place because a part of the minimum bias applied to the RF or IF tubes as the case may be is due to the plate current of the automatic volume control tube. This minimum bias however, is not the only bias applied to

the RF and IF tubes. The circuit is so arranged that a definite bias is secured by virtue of the drop across a resistor in the cathode circuit. The minimum bias secured through the automatic volume control tube is added to this bias. You should always bear in mind that the automatic volume control is in effect, nothing more than an automatically varying resistance whereby the RF or IF or both grid biases are varied. A setting of a high plate current in such AVC tubes will produce high grid bias upon the variable bias controlled tubes thus limiting the sensitivity of the receiver. A low value of plate current in such automatic volume control tube circuits will apply a low bias to the bias controlled tube, thus increasing the sensitivity of the receiver. Accordingly, the adjustment of the automatic volume control tube represents an adjustment of the sensitivity of the receiver.

In certain receivers the steady plate current of the AVC tube is fixed. That is, the grid bias applied to this tube is fixed and the minimum sensitivity level is varied by means of a volume control located in the aerial circuit or in the RF input circuit. A supplementary volume control is oftentimes located in the audio frequency amplifier system. The action of this control is independent of the automatic volume control.

Adjustment of Neutralizing Circuits

For neutralizing, following material should be available.

1. A modulated oscillator or signal generator of some kind having a frequency range equal to that of the circuit to be neutralized.
2. A long screw driver, non metallic with the exception of the point.
3. A dummy tube similar to the one used in the stages to be neutralized.
4. An output meter of some kind to indicate a balance of neutralization.

The dummy tube must be a good tube and provision must be

made either within the base of the tube or in the set that when the dummy tube is inserted into the socket, its filament or heater will not become incandescent. In all other respects the tube should be in perfect condition. However, a tube with a damaged filament or heater is not satisfactory for use during neutralization. The output meter can be connected in conventional fashion, across the speaker voice coil. If a dynamic speaker is not used, the output meter can be connected directly across the speaker winding.

The frequency adjustment of the test oscillator depends upon the circuit being neutralized. If it is the radio frequency system of the receiver neutralization can be carried out at about 1400 KC. If the circuit is the intermediate frequency amplifier, neutralization can be carried out at the IF frequency rating of the system.

The test oscillator is connected to the aerial-ground posts of the receiver and the signal is tuned in to maximum resonance as indicated upon the output meter. Then remove the first RF tube and insert the dummy neutralizing tube. There will be a decided drop in the signal output shown upon the output meter and audible through the speaker. Now adjust the neutralizing condenser or balancing coil for the tube circuit being neutralized. This adjustment consists of varying the neutralizing unit until the signal indicated upon the output meter or heard through the speaker is minimum. It may not be possible to perfectly balance the system and thus eliminate the signal from the speaker. If the speaker or the output meter does not indicate this minimum with certainty, then use the sound in the speaker or set the adjustment of the neutralizing unit midway between the two positions which afford minimum sound output from the speaker or minimum signal indication upon the output meter. Now replace the dummy tube with the regular tube and repeat the operation in the next RF stage.

The same operation is carried out in the IF stages if they are of the neutralized type. The only difference is the adjustment of the test oscillator frequency.

After the neutralizing or balancing has been completed insert the regular tubes into the sockets and check the receiver over the entire range, using the regular aerial and ground and a broadcast signal. If oscillation is obtained, a very slight readjustment of the neutralizing condensers will eliminate the trouble. It is necessary to remember that satisfactory neutralization can be obtained only when the dummy tube is of the type used in the receiver and when the circuit components are in

proper position so that no feedback other than that neutralized exists in the system. If there is feedback between leads or the coils themselves, neutralization of the tube feedback will be of little help.

Furthermore neutralization must be carried out at the operating voltages normally used. Changing the voltages will require a change in the neutralizing adjustment. Changing tubes will as a rule require reneutralization.

Section 7

APPLICATION OF SET TESTERS AND ANALYZERS.

One of the important functions of this book is to convince you that with but a few exceptions, the application of your set tester, analyzer or diagnometer is no different to a superhet than it is to any tuned radio frequency receiver. If you are familiar with the methods of determining tube operating potentials as found in TRF receivers you are experienced in the method of determining tube operating potentials in superheterodynes.

Exclusive of the few functional differences which shall be cited later, the types or tubes used are similar. As previously illustrated an RF amplifier remains an RF amplifier whether it is used in a TRF receiver or in a superhet. The basic design of the tube used is the same. The variable mu tube is applicable to the TRF and superhet with equal facility, as a matter of fact its design was based upon application in the TRF receiver. The same is true of the screen grid tube of the '24 type and the same is true of the pentode. No one of these tubes can be said to have been designed for special use in superheterodyne receivers. Accordingly, your experience in checking tube operating potentials and currents of tubes utilized in TRF receivers will stand you in good stead.

If you own any but the most modern set testers, analyzers or diagnometer equipment, it will be necessary to secure the proper adapters whereby you will be able to check the various types of pentode tubes.

Variable Mu and Pentode Tubes

What is to follow is not intended as a discourse upon these tubes. All we are attempting to do is to define these tubes with respect to the application of set testers and tube checkers. The problem of replacement is considered in Section 8.

The variable mu tube is like the type '24 except that it includes a radical design of the control grid structure. This element is designed to have a variable effect upon the plate current, in other words the amplification constant of the tube does not remain substantially the same as the grid bias voltage is varied, assuming constant plate and heater or filament potentials. The higher the grid bias applied the lower becomes the amplification constant. This is true in the conventional '24, but the rate at which the reduction takes place in the variable mu tube is very much greater. The cumulative effect of this condition is that the tube enables the application of a very wide range of control grid bias voltages before reaching the plate current cutoff point and interfering with the function of the tube as an amplifier. Such structure allows variable control grid bias form of volume control.

The variation of mutual conductance of the tube is fairly great for small changes in grid bias voltage but gradually flattens out as higher values are applied. The socket terminals for the variable mu tube are identical to those utilized for the '24 type of tube.

The power pentode is designed for use in the output stage. It derives its name from the fact that five major elements are used, wherein the filament is considered as one element and if a cathode type tube is used, the cathode replaces the filament as the electron emitter and is classed as a major element. The remaining elements within the tube are the control grid, suppressor grid, screen grid and plate, making five major elements.

The socket connections to the filament type pentode are

shown in figure 49. The arrangement of the elements within the tube difiers somewhat from the conventional.

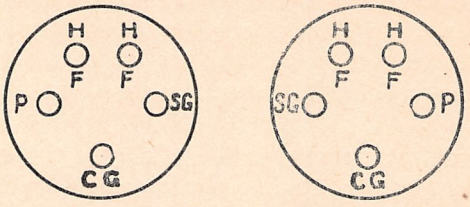


Fig. 49
Pentode tube socket and tube base

Starting with the electron emitter, be it the filament or the cathode, the location of the other elements is as follows. Electron emitter, the control grid, the screen grid the suppressor grid and the plate. The suppressor grid is at times known as the cathode grid and is internally connected to the mid-point of the filament in the filament type of tube and to the cathode in indirectly heated pentodes. The connection is made within the tube and it is impossible to insert any measuring instrument between the suppressor grid and the filament or cathode.

The function of the screen grid in the pentode is like that in the regular screen grid tube, namely to allow a high value of amplification without an undue change in the plate resistance of the tube, a very definite advantage over the conventional three element tube. The screen grid in this case is an accelerator grid, because it accelerates the flow of electrons to the plate. However, the impact of the electrons upon the plate results in the dislodgment of other electrons from the plate, generally known as secondary emission. To minimize secondary emission and the reduction of the plate current because of the secondary flow of electrons from the plate to the screen grid, the suppressor grid is inserted into the pen-

tode. This suppressor grid or cathode grid prevents the flow of secondary emission electrons from the plate back to the screen grid.

Certain precautions must be exercised when working with pentode tubes. Never operate the pentode tube without plate voltage. Such a condition may arise if the speaker is disconnected or if a change is being made in the primary of the output transformer. The tube may be damaged beyond repair and may develop an excessive gas content. It is possible that the screen grid will become incandescent under such conditions. Furthermore never operate the pentode tube without control grid bias. Without this bias the screen and plate current will rise to excessive values and damage to the tube is a hazard.

Troubles Which Do Not Influence Voltage Readings

In view of the detailed instructional material contained in the booklets which accompany the commercial set analyzer, set tester or diagnometer, and because it is impossible to list the actual controls upon each of these panels, we shall devote space to those pertinent items which influence the successful application of these devices to superheterodyne receivers. A thorough explanation of the design and application of set analyzers is contained in the "Perpetual Trouble Shooter's Manual".

Let it be known that all forms of trouble are not determinable with the set analyzer or set tester. Tube troubles and circuit troubles which influence operating voltages become evident because of the observed deviations from the rated values. However, there are certain troubles possible in a radio receiver which will render the receiver inoperative without having any effect or possibly a very negligible effect upon the operating voltages. Therefore it is highly important that you realize the following, assuming that the aerial and ground are in good condition.

When all tube voltages are normal and the receiver is not operating in perfect manner, the following may

be contributing causes:

Short circuited turns in RF, IF or AF primary and secondary windings.

Short circuited RF, IF and AF primary or secondary windings inclusive of the output transformer.

Open circuits in RF transformers which are a part of the pre-selector system and do not function as a means of applying the control grid bias.

Open circuits in the transformer connected into parallel plate feed systems of RF, IF and AF amplifiers.

Open circuited blocking or coupling condensers in RF, IF and AF systems. (This is the condenser usually connected between the plate circuit of one tube and the grid circuit of the next tube.)

Open or short circuited dynamic speaker voice coils.

Short circuited or defective condensers connected in shunt with RF, IF or AF transformer primaries or secondaries.

Short circuited or defective resistances connected in shunt with RF, IF of AF transformer primaries or secondaries.

Tuned circuits out of alignment.

Speaker armature or voice coil, depending upon type, incorrectly centered.

Compensating or neutralizing condensers out of adjustment.

Open circuited bypass condensers in tube circuits.

Open half of filament shunt resistor.

Open hum neutralizing system.

Short circuited plate coils in autodyne and oscillator systems.

Short circuited grid coils in oscillator.

The list appears formidable, but it is narrowed down by the correlation of the trouble and symptoms described in Section 4.

Checking Operating Voltages and Currents

In certain respects, the modern superheterodyne receiver presents a few peculiar conditions during the testing of voltages and currents. Not so much because it is a superhet but because of the circuit design employed in modern systems.

One of the paramount items experienced in connection with voltage and current tests upon such receivers is the

possibility of the development of an oscillatory state during the time that the grid and plate voltages are being determined. This applies equally well to RF and IF stages. However, such a condition is most frequent when the control grid lead is a part of the cable. When separate such trouble is seldom encountered. The symptom may appear as a whistle or as motor boating.

Another important consideration is the measurement of grid bias voltages in circuits which contain a high value of resistance in the grid circuit. In such cases the voltage indicated upon the meter will be appreciably less than the actual bias applied. The best method of determining the actual grid bias voltage will be to measure across the cathode resistor.

To minimize oscillatory effects, the receiver should be tested without any signal input. The setting of the volume control will affect the voltage and current specifications. Set the volume control as specified in the voltage table.

Plate current and plate voltage tests upon oscillators should be made in point fashion. The same is true of the grid bias. With respect to the latter it is possible that the grid bias when measured across a resistance in the cathode circuit will be influenced by the frequency of the oscillator tuned circuit. It might be well to remember that the use of a set analyzer plug and cable to check oscillators may interfere with the normal operation of the oscillator. Make voltage and current tests with the aerial and ground disconnected.

A large number of superhets make use of resistance capacity coupling between the demodulator and the pentode output tube. When measuring the grid bias applied to these tubes, the usual grid to ground test is apt to show a voltage reading much less than that actually applied to the grid. In view of the fact that various forms of securing the control grid bias are used, it is best to

consult the wiring diagram for the bias voltage test points.

When making tube voltage and current tests it might be well to bear in mind that the resistance specifications as employed in wiring diagrams represent manufacture tolerances of from 5 to 10 percent. With possible variations in tubes, there may be a variation of from 10 to perhaps 20 percent in the rated voltages and currents and the actual voltages and currents. The final decision as to the condition of the receiver depends to a great extent upon the operating observations made by yourself.

There are some instances where the location of the volume control is such as not to cause any effect whatsoever upon the tube operating voltages and currents.

As a rule, when checking pentodes, you will find that the voltage between the screen grid and cathode or filament is higher than the voltage between the plate and cathode or filament. This is due to the voltage drop across the primary winding of the output transformer.

When utilizing commercial set testers, analyzers or diagnometer kits remember that most of the meters are of the multirange type. In order to secure the most discernible indication you should select the proper meter scale according to the anticipated reading. If you are not aware of the reading to be expected, *use the highest meter range as a precautionary measure.* Then reduce the range until the meter indicates a reading which can be read with the greatest ease. Always look right down upon the meter or if the meter is in a vertical position, look straight at the meter. Never make readings from an angle. Making readings from an angle introduces an error.

One make of superhet, the RCA 43, utilizes at the time of this writing an unusual output tube arrangement. The output tube grids are heavily biased so that the normal tube plate current is only a small fraction of that to be expected in a tube of this type. Actually the steady no-signal plate current for each of the type '45 tubes is only about .5 milliampere. However, when a signal flows through the system, the plate current increases. The

reason for utilizing such a system is the possibility of securing about four times the output of the conventionally biased push pull system. The value of the bias is that to produce substantially plate current cutoff.

In the event that any one particular stage goes into oscillation during the measurement of the tube operating potentials, it is best to remove the tube from the tester and to replace it in the receiver and make point to point voltmeter tests. Current tests should be made with break-in adapters having very short leads. Be careful to keep all meter leads away from other parts of the receiver circuit.

Checking Gassy Tubes

Generally speaking a gassy tube draws more than the required plate current. Futher, the operation of the tube is such that the excessive plate current drain develops after a short period of normal plate current operation, the plate current starting at normal and gradually increasing as the degree of ionization within the tube becomes more and more. In some instances a substantial gas content causes grid current.

When the gas content is excessive, the tube will glow with a purple or bluish tint. Many time the ionization is caused by the application of excessive operating potentials and in other cases the development of the gas within the tube is due to liberation of the gas during overload. Reducing the plate potential and with substantial reduction in grid bias in order to obtain the proper operating condition may mitigate the trouble. The presence of excessive gas is manifest as fading upon local stations, fluttering reception and when the trouble is located in the pentode tube or in the output tubes, as a buzzing sound audible through the speaker.

However, we hasten to mention that the general run of power pentodes have a gas content and even glow with a bluish tint but this does not mean that the tube is unfit for use. Judgement must be rendered after consideration of the performance of the tube. The effect of gas in automatic volume control is dis-

cussed in another paragraph under that heading, listed elsewhere in this section.

Correcting A Trouble In Tube Circuits

Pentode tubes in which the grid current is higher than normal, overload readily when the grid circuit contains excessive resistance. This condition may be manifest by fluttering reception. buzzing and other noises. Also, short tube life. A remedy is the reduction of the resistance in the grid circuit. If as in some Stewart Warner receivers a high value of fixed resistance is located between the control grid and the high end of the grid leak in the pentode stage, and one of the above troubles develops, it is a good idea to remove that resistance. In the case of the Stewart Warner R 101 and R 102 receivers, this resistor should be transferred into the circuit between the high end of the pentode grid leak and the grid end of the blocking condenser.

Checking Variable Mu and Pentode Tubes

As stated elsewhere in this section, the variable mu tube can be checked just as if it were a '24 tube. The pentode however can best be checked by utilizing an adapter which will give access to each of the circuits. Such an adapter is placed into the receiver tube socket and the tube is inserted into the adapter. Each of the tube elements with the exception of the suppressor grid is accessible through external contacts upon the adapter. Provision is made for the checking of the various currents by the insertion of current meters into the various circuits. For routine checking follow the instructions given in the booklets which accompany the modern set testers which have provision for pentode checking or secure the required adapters and follow the instructions accompany-

ing these adapters. We refrain from constructional details covering these adapters because of the low purchase price for finished units and the fact that the commercial products are of the simplest and most practical design. with conservation of space accomplished.

Checking Distortion Due to Tube Overloading

The most practical method of checking for distortion due to tube overloading, is the consideration of the tube operating voltages and reduction of the signal input. First measure the tube operating potentials. Low screen, control grid or plate voltages will cause tube overloading if the signal input is in excess of that permitted by the potentials being applied. With normal filament, control grid and plate voltages, sub-normal screen grid voltages cause overloading of RF, mixer, or demodulator tubes. The same is true in the case of the pentode. If the observed voltages are the rated voltages, the remedy depends upon the intensity of the signal desired. If the overloading occurs upon abnormally strong signals, it is necessary to reduce the signal input. You must recognize that situations arise where the signal input is far in excess of the values considered in the design of the receiver. If the demand exists for maximum signal output and operation of the volume control "full on" results in distortion, the only remedy is reduction of the volume control. Once again it is necessary to remember that every receiver is designed to afford a certain amount of undistorted output with a certain signal input and the volume control full on. There are times when the receiver is not capable of furnishing the amount of sound output required, which means that the type of receiver selected for such work was not correct. The presence of a distorted signal in such cases is not the fault of the installation. Do not tamper with the values of resistance utilized to

maintain certain operating voltages upon the tubes.

The modern radio receiver consists of a number of correlated electrical units. They are interdependent. This is particularly true in the case of AC operated receivers. If you change one resistor so that the plate voltage and plate current values for one tube are increased, the other tubes in the receiver will suffer unless you make the required changes upon all of the voltage reducing resistances and the voltage divider. As far as voltage increase is concerned, it is a very dangerous operation. Do not apply operating voltages in excess of the tube manufacturers rating. Furthermore the application of higher than the receiver manufacturers rated values is apt to cause very many undesired effects in a sensitive receiver such as the superheterodyne.

The old and oft mentioned method of checking for distortion in the output stage of an amplifier is still effective. Insert a milliammeter in the output tube B supply lead. It should have a range sufficiently great so that the normal plate current will be about half of the full scale. Set the receiver into operation. Note the action of the meter pointer. The permissible fluctuation for satisfactory reproduction during the passage of signals should not exceed about 5 to perhaps 10 percent of the total deflection. The steadier the meter needle the better.

Tubes used in parallel or push-pull should be of like characteristic. Equal mutual conductance and plate current are greatly desired. It is assumed that these two constants are checked at like values of plate, filament and grid potential. Checking for plate current only is not a very satisfactory method because a variation in amplification constant is apt to result in like values of plate current for similar plate voltage, yet the tubes will not be of like characteristics. The tubes should be checked by noting the *change in plate current* rather than the steady plate current only, although the steady value is also of importance.

Checking Automatic Volume Control Systems

Automatic volume control tube circuits cannot be checked in normal fashion, that is with the set analyzer plug and cable system. This is due to the method of employing the tube in the receiver.

In the first place there is no steady DC plate voltage upon the plate of the combination diode automatic volume control-demodulator tube. The plate voltage required for the rectifying action is furnished by the signal itself.

In other types of automatic volume control tube circuits, the plate of the AVC tube is at ground potential, yet is at a higher potential (positive) than the most negative part of the voltage divider. Such a circuit arrangement does not allow the routine voltage test for several reasons. First, because such circuits as a rule, contain a number of resistors which will cause a voltage reading very much less than that actually found in the circuit. Second, the return points are not always those employed in the receiver circuits, which means that the return circuit in the tester system would not be the correct one. Third, some AVC tube systems specify the points across which one must make voltage measurements in order to determine the actual voltages present in the system. This means, that the voltmeter in the analyzer or tester must be employed with external leads and point to point measurement is the only means of accurately determining the voltages in the circuits.

In view of the fact that the grid circuit of the AVC tube is as a rule connected to the IF or demodulator tube plate circuit, poor results may be expected when the set analyzer cable plug are inserted into the AVC tube socket and the AVC tube is placed into the analyzer test socket.

Detecting Oscillating Circuits

The plate current of the tube which is oscillating may be less or more than the rated plate current for a non-oscillating condition. If the grid circuit of the tube does not contain a fixed condenser and leak the plate current will increase if the tube is oscillating. In the majority of cases when the grid circuit contains a grid condenser and leak the plate current will be less than the normal to be observed in a non-oscillatory state. A determining influence is the grid bias applied.

As far as the other circuits in a superhet are concerned, grid current will flow during an oscillatory state and the plate current will show a definite increase. The presence of grid current and higher than normal plate current, combined with the fact that if the finger is touched to control grid lead decreases the plate current to approximately its normal value, is a sure sign of an oscillatory state in that stage. Of course, heterodyning during tuning is also a sign of oscillation but it may be difficult to select the amplifying stage at fault. The finger test is simple, practical and informative. It should be made without signal input to the receiver.

General Continuity Testing

In view of the fact that the majority of set analyzers include continuity testers in the form of calibrated ohmmeters, a few words about such units will not be amiss. In as much as a continuity test in the superhet is identical to a continuity test in a TRF system, there is no need for special description. However, it might be well to mention that all windings possess resistance just as regular resistance units and a check for resistance is the best method of determining a defect in the winding.

Another important consideration present in superhets and somewhat lacking in the TRF receivers is introduced by recent

developments in receiver design. It has become customary in superhet design to make use of electrolytic type bypass condensers across voltage dividers and filter resistances and across bias resistances in the audio system. The regular resistance test across these resistors is apt to produce confusion if the bypass condenser is permitted to remain connected across the resistor during the test. In contrast to the regular solid dielectric (paper or mica) fixed bypass condenser, the electrolytic condenser is polarized and also has a much lower resistance, in fact allows a certain amount of leakage current, about .25 to .5 milliampere per microfarad. This means that if the parallel circuit of the condenser and resistor are being checked, it is important that the polarity of the test voltage applied be correct and recognition be accorded the presence of the condenser. The best step is to disconnect one of the condenser leads when checking any circuits shunted by an electrolytic condenser.

Such condensers cannot be checked for a charge. They must be checked for leakage current.

As in the case of TRF receivers the use of the ground as a common point for continuity or resistance measurement depends upon the design of the receiver. The best method of determining whether the ground or chassis may be used as one common continuity test reference point is to examine the wiring diagram.

Section 8

PECULIARITIES IN COMMERCIAL SUPERHETERODYNES

The comparatively small size of this book does not permit a complete listing of the peculiarities to be found in commercial superheterodynes. By peculiarities we mean circuit design different from conventional structure. Perhaps the following tabulation will prove of interest. They apply to receivers available at the time of this printing.

1. Resistance coupling is very popular between the demodulator and output tube. This is true even in what is known as push-pull systems. Conventional set analyzer tests are not applicable. Point to point tests with voltmeters and ohmmeters must be used.
2. The bias voltage of oscillators may be found to vary according to the frequency of the oscillations being generated by the oscillator tube.
3. The speaker field is the source of the output tube bias voltage. Sometimes a voltage divider is connected across this field winding and a portion of the voltage developed across the field is used as the output tube grid bias.
4. Watch out for defective coupling condensers in inductive and capacity coupled RF systems.
5. Watch out for open end windings and for link circuits in RF and IF transformers. As a rule the ground connection cannot be used as a common junction for the continuity test.
6. Watch for electrolytic type bypass condensers across bias and voltage divider resistors.
7. High value of bypass condenser is used across pentode tube grid bias resistor.
8. Keep RF and IF grid and plate leads away from chassis

and control grid leads from each other.

9. Plate circuit filter resistance are utilized in most superhet audio systems.
10. As a rule the pre-selector RF circuits are between the aerial and the first tube, be it the RF or the mixer.
11. In some receivers, the secondary circuit of one of the IF transformer contains a fixed resistance ranging from about 200 to 400 ohms. This fact must be remembered if the occasion ever arises to make a resistance check of the winding.
12. All receivers employing volume control do not limit the variable control bias to the RF or IF tubes. Some receivers control the RF, Mixer and IF tubes control grid bias.
12. When checking receivers which employ an AVC tube, make the tests with the aerial and ground disconnected and without signal input.
13. In some receivers (Zenith 91-92) the "local-distance" switch shunts a fixed resistor between the plate and cathode of the AVC tube thus maintaining a steady bias upon the RF, Mixer and IF tube grids.
14. Quite a few RF circuits employ series fixed condensers in the tuned circuits. This condenser is in series with the variable, permitting the coil return to one part of the system and the connection of the tuning condenser rotor to ground.
15. Some receivers locate the demodulator tube RF choke within a shield and ground the shield. See to it that this ground is perfect and that the shield is in place.
16. Some systems use shielded braid around the wires from the Mixer and IF tube plates to the coupling units in the plate circuits.
17. Grid filter resistances are employed in the RF, Mixer and IF circuits in the majority of receivers which use automatic volume control. Grid filters are also used in the audio systems.
18. The shorter the aerial the better.

Elimination of Noise

We made mention of the fact that one peculiar condition accompanying the use of automatic volume control is that the noise level increases when no signal is

tuned in. This is due to the fact that the sensitivity of the receiver is highest at such times. The moment that a signal is tuned in, the sensitivity is controlled and the noise level decreases.

Receivers possessing the sensitivity of a good superheterodyne are confronted with the problem of noise pick-up. One precautionary measure which should be taken with all such receivers is the use of a capacity filter across the power line. Many receivers are equipped with such filters. The filter is connected across the AC connections to the power transformer. If none is used in the receiver, connect two .5 mfd condensers in series. (They should be rated at least 250 volts DC.) The junction between the two condensers is connected to ground. The two outside leads of the series combination are connected across the power line.

In view of the fact that noise pickup is a problem, the following data (compiled by the RCA Service Department) pertaining to aerials and noise, should be a value. There may be said to be three conditions of noise pickup. The first is zero noise level with the aerial and ground disconnected but equal noise level with indoor or outdoor aerial. The second is when the noise level is the same with or without the aerial. The third is when the noise level with an outdoor aerial is excessive whereas the signal pickup with the indoor aerial is not sufficient for satisfactory reception.

The problem in the first example is pickup by the aerial leadin within the building. One solution is to locate the receiver close to where the leadin enters the building and to use short ground leads. Another possible solution is the use of a copper braid around the aerial leadin and if necessary around the ground wire. The shielding braid is not grounded.

The problem in the second example is the entry of the noise through the power supply lines. A filter as stated above should be used. If when used, the condition mentioned as example one appears, the suggested solution should be employed.

In connection with a high noise level without any aerial or

ground it is also necessary to investigate the receiver in order to make certain that the trouble is not due to a defect within the receiver, such as an overloaded resistor or one which is bad, poor contacts, defective or leaky bypass condensers, etc.

In the third example, the probable trouble is noise pickup by the aerial leadin. The suggested remedy is a copper braid around the entire leadin or the use of shielded leadin wire from the receiver to the flat top portion of the aerial. Whether or not the copper braid or the shield shall be grounded must be determined by experiment. Changing the direction of the aerial may be of some aid.

Another possible source of noise is a loose ground contact or contact between the ground wire connected to a certain ground, with another ground of different character. Still another source of noise is intermittent grounding of the aerial or intermittent contact between two aerials. Wherever possible, use water pipe grounds. Steam pipe or radiators properly cleaned so as to secure a clean contact surface rate second. Gas pipes make very poor grounds. Make the ground lead as short as posisble.

Keep aerial leadin wires away from steel girders and beams. Keep all indoor aerials away from girders, beams or other masses of metal.

Checking For Noise

One of the most difficult service problems is to locate a unit which is causing noise in the receiver. When you feel reasonably certain that the noise originates in the receiver, proceed as follows: Remove the aerial and ground. Adjust the volume control on full. Place the wiring diagram of the receiver in front of you. Starting with the aerial system, remove the first tube nearest the aerial. If the noise continues, you can be reasonably certain that the noise originates in some system following the first tube. Replace the first tube and remove the oscillator. If the noise ceases, try a new tube as the oscillator. If it continues with the new tube in place, check the various units in the oscillator system inclusive of the coupling circuit. If the oscillator is also the mixer, check the complete circuit. The most

likely units which will cause noise are the fixed condensers and the fixed resistances. Check all connections to the fixed condensers. Try disconnecting one lead from the fixed condenser under observation. If the noise ceases, replace that condenser. Do not disconnect more than one condenser at one time. If you do you may be troubled by excessive regeneration which will aggravate the noise difficulties.

As to resistances, you will have to refer to the diagram to ascertain the position of the resistor in the circuit and whether or not short circuiting that resistor is apt to cause damage. If the function of the resistor is to limit applied voltages, replacement must be resorted to instead of short circuiting. Bleeder resistances should not be shorted. Such a short circuit will cause material increase in applied potentials. It is better to open circuit one of the leads to the resistance. This may cause a variation in applied potentials but they will not be as harmful as a short circuited bleeder.

An alternative method of isolating noise, if you do not wish to remove the tubes is to ground the grids, that is the control grids. This does not mean short circuiting the bias resistor. If the noise ceases, the probable location of the defect is somewhere in the circuit between the grounded grid and the previously tested system.

The most practical method of checking for the probable origin of noise known to be due to a defect in the receiver is to alternately short different parts of the amplifying system, effectively short circuiting the amplifying circuit but not in a way to damage the tubes. Start with the aerial circuit and work towards the speaker. The aerial and ground should be disconnected and the volume control should be on full. If the noise is present then the units immediately preceding the circuit shorted or that circuit is the probable location of the trouble. Make certain to examine the complete circuit. Generally

speaking replacement is the only sure test of a unit under suspicion. Bypass condensers can be checked by disconnecting one lead.

Variable Mu And Pentode Tube Replacement

This subject has been the topic of many inquiries. Whether the change is one requested by the owner of a radio receiver or whether the effort is being made to modernize a receiver or to correct a fault, is not known, but the fact remains that a very great number of inquires are received relative to such changes. Unfortunately, the answer cannot be a single word, affirmative or negative. There are numerous items to be considered.

Consider the '51 type of tube. The first is that the purpose of the tube is the alleviation of a certain type of difficulty encountered in receivers. This difficulty is cross modulation, or the presence of two stations, when the receiver is tuned only to one. Expressed in the simplest manner, this trouble is not due to imperfect selectivity but to incorrect operation of the amplifier tube being used. By a change in the design of the tube it has been possible to apply a much greater signal voltage, also bias voltage without causing the RF amplifier to act like a detector. The change is of such character that the bend in the lower end of the grid voltage-plate current characteristic curve is much more gradual as the grid bias voltage is made more and more negative.

Accordingly, the first requirement, in order to justify the change, is that some form of cross modulation difficulty be existent when the original '24 type tubes are being used. If the receiver is performing in normal manner as far as local-distant control and selectivity are concerned, there is no definite need for replacing the tube '24 RF amplifiers with the type '51 tubes.

Second, is the consideration of the type of volume control. In order that the correct operation of the '51 tube be obtained, it is imperative that the screen voltage be held constant. This means that receivers employing the variable screen voltage form of volume control are not suited for use with the '51. In order to enable the use of the tube, this condition requires a complete revision of the volume control system, at least from variable screen grid voltage to variable control grid bias.

Third, is the fact that in order to enable the use of variable

control grid voltage, it is necessary that the receiver be specially designed along such lines. At least the voltage divider system must be designed along such lines, so as to compensate for the variation in the other operating voltages when the control grid bias is increased. We consider the increase only because of the fairly low normal bias requirement.

Fourth, is the increased plate current requirement of the '51 tube. The average difference in plate current for a fixed and constant value of plate and screen potential applied to the '25 and the '51 approximates about 50 percent more in the case of the '51. This means alternation of the value employed in the voltage divider system in order to allow the application of the required operating voltages with the increased current drain.

Fifth, is the item of automatic control equipped receiver. While it is true that the action of the volume control system is a variation of the control grid bias and it would appear as if the system is ideally suited to the variable mu tube, there are very few, if any, cases where the change is recommended.

A sixth consideration is the actual change of the RF transformers. There is a difference in the impedance characteristics of the '24 and the '51. If a receiver has been designed for use with the '24 tube it is best that it be used with that tube. The use of a different tube is apt to disturb the balance of the receiver and while it is possible that the '51 tube may be of the character to afford better sensitivity, the change may also result in a condition which will be troublesome to remedy. At the same time it is possible that a change of this type will result in a loss in sensitivity rather than a gain.

Upon the surface one would be prone to say that a change in the voltage division system of the receiver is a fairly easy task. Such may be true in a few isolated cases, but an investigation of complete voltage divider systems used in the receivers manufactured during 1929 and 1930, shows that the changes are fairly complex. It is the general consensus of engineering opinion, that the change should not be made. What appears to be the major difficulty is the revision of the voltage divider system so as to enable the application of a variable control grid bias of from about 3 to perhaps 45 or 50 volts, with very little change in the screen grid voltage.

Replacing Output Tubes With The Pentode

The basic advantage of the pentode output tube is found in the output power versus the input grid voltage. This tube, by

providing greater power output for lower input signal voltage than any other output tube, affords a definite amount of economy as far as cost of operation is concerned. Under the circumstances, when this item is considered to be paramount, there is a definite advantage in the use of the pentode output tube. However, replacing a single '45 or a pair of '45s in a receiver which has been in operation for a period of time is an entirely different item. No longer is it necessary to consider the subject of economical operation. If the original system makes use of 5, 6 or 7 tubes, there is no actual economy achieved by replacing the '45 with the '47. As a matter of fact the actual cost of the units which must be changed when the tubes are changed is of such figure that when broken down for comparison with the actual differences in the cost of operation per hour, day or month, the additional cost to make the change amounts to more than the difference in maintenance for more than a year. Thus there can be no logical reason for making the change other than the effort to "keep up with the Jones'."

It is true that the power output of the pentode power tube is about 50 percent more than that the '45 type for a constant plate voltage of 250 volts and normal peak signal voltage of about 50 volts in the case of the former and about 16.5 volts in the case of the latter. This appears to be an advantage. However, it is also important to consider several other controlling influences which are introduced because of this wide variation in required input signal voltages. Recognizing that the original receiver is designed to supply the required 50 volts peak signal voltage to the '45 tube, some means must be provided to limit the input voltage to the pentode to the required 16 volts. This means that the sensitivity of the receiver must be greatly reduced when the pentode replaces the '45.

Perhaps it will be well to elaborate upon this statement so as to make certain that it will not be misunderstood. The previously made reference to reduction of general RF sensitivity to accommodate the pentode is true only when the pentode tube replaces the '45 tube in an existing receiver. The statement is not true when the original receiver is designed for use with the pentode power output tube. Recognizing a certain RF sensitivity requirement, the usual change made in the modern receiver design is the omission of the first audio frequency amplifying stage.

Returning again to the instance where the '47 replaces the '45, it is necessary to reduce the value of the signal voltage

being fed to the pentode tube. Several methods are possible. One is to arrange a voltage divider across the system connected across the control grid and cathode or filament of the pentode. This is seldom if ever employed. A second arrangement is to reduce the sensitivity of the RF amplifier. The consequences of this change depend upon the exact design of the system. If the circuit utilizes the variable grid bias form of volume control, excessive grid bias may result in distortion in the RF system due to a possible alteration of the operating characteristics of the RF tube by virtue of the greatly increased bias. If the volume control is of the variable screen voltage type, a similar condition may ensue, depending upon the exact design of the system. Each of these conditions have been experienced in actual practice. As far as the tube itself is concerned, the major difference with respect to plate voltage, grid and plate current values is the required grid bias. The normal plate voltage of 250 volts is applicable in both cases. The plate currents are practically identical, although, to be exact, that drawn by the pentode is a few mills less. The difference in grid bias is very marked, that required by the pentode being about one-third of that required by the '45. Under the circumstances, one would imagine that the only change required to accommodate the pentode is the change in the value of the grid bias resistance.

Actually such is not the case. While it is true that the aforementioned is the only alteration related to voltage distribution, another change is occasioned by virtue of another constant of the tube. This constant is the plate impedance. That of the pentode is many times that of the '45, perhaps twenty times as great. This means that in order to apply the required load impedance, the output transformer must be changed. That used with the '45 is not suitable for use with the '47, not if a satisfactory amount of power output with minimum distortion is desired.

As to the presence of the second and third harmonics in the pentode and the general freedom from such harmonics in the case of the '45, very little need be said in as much as there is a wide variation in the actual harmonic content of the signals passed through the various manufactures of pentodes and the efforts being made to correct this situation.

We can summarize the entire situation by stating that very little is gained by replacing a '45 tube with a pentode in an existing receiver where there is an abundance of RF amplifiers and where the power output is entirely satisfactory.

Section 9

DESIGN OF RF AND IF OSCILLATORS

The following material is offered to the individual who wishes to construct his own oscillator equipment.

The first essential characteristic of an oscillator intended for receiver alignment is minimum radiation from the oscillator circuit. Whatever energy is to be fed from the oscillator to the circuit to be tested must be transferred through the regular channels. This means that the complete oscillator must be shielded. Further, that RF filters must be used to keep all RF energy out of the line circuit, assuming that the oscillator will be suitable for use with batteries or AC or DC. Personally we prefer strictly battery operation for reasons set forth in a preceding section. AC or DC operation is included in order to make the instrument as versatile as possible.

The second essential characteristic is that the oscillator have an output approaching a constant figure. Critical coupling must be avoided. This means that the circuit structure must be such as to assure steady and consistent coupling over the entire band.

The third essential characteristic is that the system be rich in harmonics. If it is to be a combination RF and IF instrument, with the IF frequencies as the fundamental, the instrument should be capable of supplying fairly strong harmonics up to and including the tenth.

The fourth condition desired is that the instrument be self modulated. This is due to the demand for economical construction.

The fifth consideration is the wave length band and the need for unmodulated and modulated output. The fundamental wavelength band must cover from 130 to 270 KC.

The wiring diagram is shown in figure 50. The constants are designated. The winding form for the major

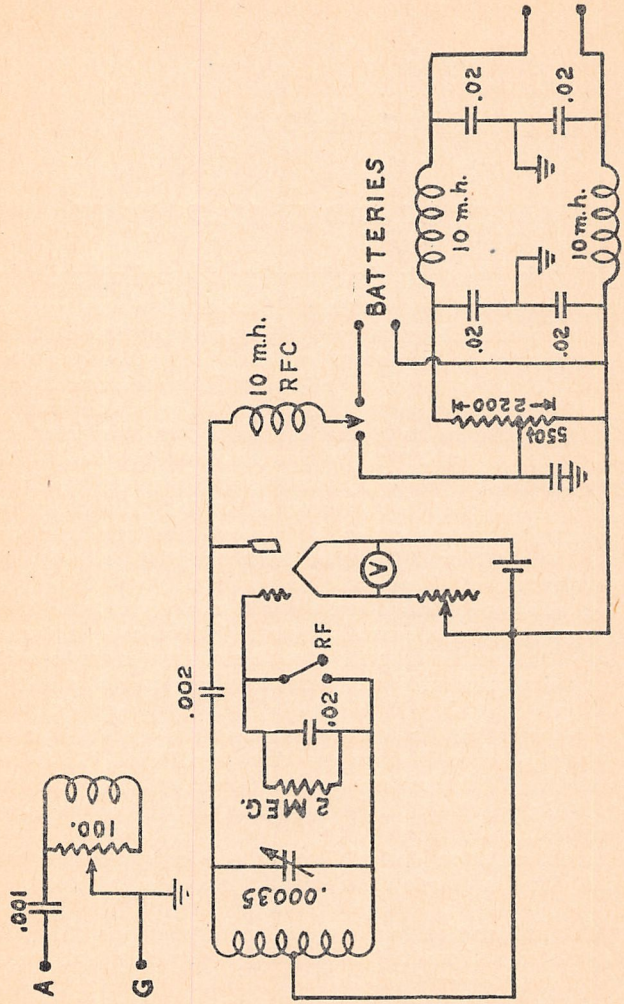


Fig. 50
Combination RF—IF Oscillator

coil is shown in figure 51. The length of the winding is 1.5 centimeters (.6 inch). The wire used is No. 20 DCC and 14 turns are wound upon each layer. The depth of the

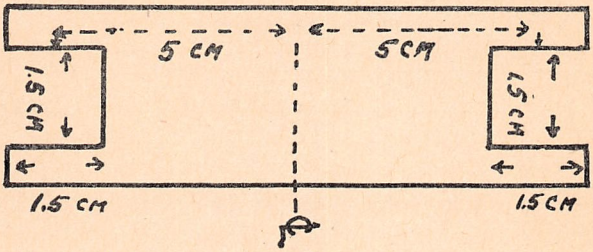


Fig. 51
RF—IF Oscillator Winding Form

winding is 1.5 centimeters (.6 inch) and 14 layers. The radius of the winding from the centre of the form of the centre of the winding, that is the 7th layer is 5 centimeters, about 2 inches. The midtap connection is taken off at the 98th turn. A switch shunts the grid leak-condenser combination. When closed it permits the generation of an unmodulated wave assuming DC plate potential. With the switch open the signal will be modulated. The voltmeter is used to enable correct adjustment of the filament voltage as the output of the battery decreases. Either battery or power line may be used for plate potential. The switch in the tube plate voltage circuit determines which system is used. The location of the tap upon the 2,200 ohm voltage, divider applies about 30 volts to the plate of the tube. The tap is taken off at 550 ohms.

The coupling coil has a radius of about 1.5 inches and consists of 10 or 12 turns. This winding is wound in haphazard fashion, tapped and fastened to the side of the main form so that it is in inductive relation to the main winding upon the form. The constants of the tuned circuit are such that the approximate fundamental frequency band of the oscillator is from about 105 KC to about 270

KC. The dial control should be of the vernier type.

Since a standard oscillator is not available in the shop of the man who will build this unit, we shall describe a practical method of calibration utilizing a standard accurately adjusted broadcast receiver and standard frequency broadcasting stations.

The calibration of the oscillator shall be carried out over the broadcast band, although the fundamental frequencies being generated by the oscillator are within the intermediate frequency range. By calibrating the harmonics of the intermediate frequencies we reduce the error when plotting the intermediate values. We shall start with the harmonics and work back to the fundamental.

Set the receiver into operation. Use a small indoor aerial, the length of which will be determined by the sensitivity of the receiver. Adjust the oscillator to be calibrated so that the output is unmodulated. Then connect the "A" and "G" terminals to the aerial and ground posts and tune in a broadcast station of known frequency around 1400 KC. Adjust the tuning accurately. Start the oscillator and tune the dial towards the highest figure, which would be the lowest frequency. Adjust accurately for zero beat with the broadcast carrier. Adjust the oscillator volume control for minimum output required to permit satisfactory adustment.

Zero beat shows that the oscillator, at that dial setting is producing a signal of a frequency equal to that of the broadcast carrier. Record the dial setting for this 1400 KC signal. However this is a harmonic and we must determine the fundamental. Remove the indoor aerial and without disturbing the tuning of either the receiver or the oscillator, adjust the latter to generate a modulated wave. The signal response from the receiver should be maximum. Now, without disturbing the setting of the oscillator dial, advance the volume control of the receiver and slowly tune the receiver dial to a lower frequency, tuning carefully until the modulated signal being generated by the oscillator is again heard. Note the frequency setting upon the receiver dial.

Suppose that the signal is received at approximately 1283 KC upon the receiver dial. Now, the frequency difference between the first setting of 1400 KC and the second setting of approximately 1283 KC is 117 KC. Since the harmonic is always a multiple of

the fundamental, dividing the frequency difference between the two settings into the higher or the lower frequency signal will give the order of the harmonic. If the frequency difference is correct it will divide evenly into the harmonic frequency. Dividing 1400 by 117 gives a quotient of approximately 11.9. Apparently the correct frequency difference is not 117 KC, which means that the second reading is not absolutely correct. The nearest even number to 11.9 is 12. Perhaps 1400 is the 12th harmonic of some fundamental. If so what is it? Dividing 1400 by 12, we secure a quotient equal to 116.6. Subtracting 116.6 from 1400, we secure the answer 1283.6 KC Thus the 1400 KC setting upon the oscillator dial is also the setting for 1283.6 KC and the fundamental is 116.6 KC Multiplying 116.6 KC by 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11, we have secured the harmonic frequencies for that fundamental. They are approximately 233 KC, 349.8 KC, 466.4 KC, 583 KC, 699.6 KC, 816.2 KC, 932.8 KC, 1094.4 KC and 1166.6 KC, and 1283.6 KC. The 12th harmonic is 1400 KC. The accuracy of the 6th, 7th, 8th, 9th and 10th harmonics can be checked by tuning the receiver to these frequencies without disturbing the oscillator dial.

With these figures as a reference we can select another point upon the oscillator dial which will enable more uniform checking where even numbers are used throughout. The fractional values experienced in the first case were due to the fractional value of the fundamental. By selecting a fundamental which is an even number the harmonics will be even numbers. Whatever numbers are selected, should be multiples of 10 because the frequency allocations are upon that basis. The nearest even number for a fundamental which would be a multiple of 10 is 120 KC. The 12th harmonic of this is 1440 KC, which would mean increasing the frequency setting of the receiver dial. This we do not wish to do because of the limitation of the maximum receiver dial frequency at 1500 KC and because calibration moving down the frequency scale is much simpler. Accordingly we select the 11th harmonic of 120 KC which is 1320 KC. Set the receiver dial accurately to 1320 KC. Now vary the oscillator tuning dial very slowly towards a lower figure. A slow movement is essential because the difference between the original setting and the new setting required is only 4 KC. Within a few divisions away from the 116.6 KC setting a signal will be heard in the receiver. This will be the 120 KC fundamental setting of the oscillator and the 11th harmonic or the 1320 KC signal is being picked up by the receiver. Record this

frequency is 1300 KC. Set the receiver dial exactly to 1300 KC KC setting. This adjustment can be checked by decreasing the receiver dial setting by 120 KC to 1200 KC, which is the 10th harmonic of the 120 KC fundamental. The signal should be maximum at this point. Further checking can be carried out by decreasing the receiver dial setting to 1080 KC, 960 KC, 840 KC, 720 KC and 600 KC. All of these frequencies should be recorded as being available at the oscillator adjustment for the 120 KC fundamental. The next higher even fundamental which is a multiple of 10 is 130 KC. The 10th harmonic of this frequency is 1300 KC. Set the receiver dial exactly to 1300 KC and slowly reduce the dial setting of the oscillator until the signal is heard. There will be no signals heard between the 120 KC setting and the 130 KC setting until the latter is reached because there is no harmonic of any frequency greater than 120 KC and less than 130 KC, which will equal 1300 KC. When the signal is heard tune the oscillator to maximum resonance and record the division number for 1300 KC. This same setting is also the location for 260 KC, 390 KC, 520 KC, 650 KC, 780 KC, 910 KC and 1170 KC, these being the 2nd, 3rd, 4th, 5th, 6th, 7th, 8th and 9th harmonics of the 130 KC signal. The position may be checked by tuning the receiver accurately to 1170 KC.

The next even number for the fundamental is 140 KC. The 8th harmonic of this frequency is 1120 KC. The 9th is 1260 KC. Choose either of these setting upon the receiver tuning dial. The lower setting is apt to give greatest response. Say that the dial is set to 1120 KC. Move the oscillator dial slowly away from the 130 KC setting towards a lower number upon the dial, which would be a higher frequency. The next signal heard should be that of the 1120 KC signal, the 8th harmonic of the 140 KC fundamental. Tune the oscillator accurately. This setting upon the oscillator is for 140 KC as the fundamental and the 2nd, 3rd, 4th, 5th, 6th, 7th and 8th harmonics equal to 280 KC, 420 KC, 560 KC, 700 KC, 840 KC, 980 KC and 1120 KC. The setting may be checked by tuning the receiver dial to 560 KC, 700 KC, 840 KC and 980 KC.

The remainder of the oscillator dial is calibrated in similar fashion, always advancing the oscillator dial and always reducing the harmonic to be tuned in by 1. Thus the adjustment of the receiver dial for the 150 KC setting would be the 7th harmonic, maybe the 6th, that is either 1050 KC or 900 KC. The higher the frequency adjustment of the oscillator the

lower will be the order of the harmonics which fall within the broadcast band.

A Calibrated Ohmmeter

The ohmmeter shown in schematic form is that suggested by the Gulbransen Co. of Chicago in their service manuals. The wiring diagram is shown in figure 52 and the calibration curves in figures 53 and 54. The

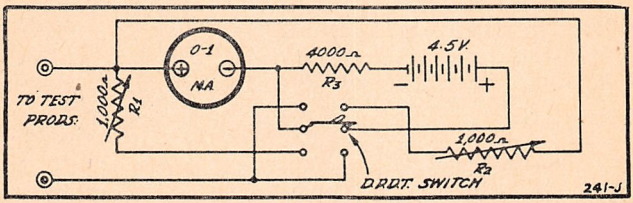


Fig. 52
Wiring diagram of ohmmeter

milliammeter is a DC instrument O to 1 mil scale and may be of the Weston 301 or Jewell patten 54 or 88 style. R1 and R2 are variable 1000 ohm resistors. R3 is a fixed 4000 ohm resistor. The battery is a 4.5 volt C battery. According to the service manual the calibration curves were made with a meter of 33.5 ohms internal resistance. Meters with slightly higher or slightly lower resistance will not cause very appreciable errors in the calibration. The errors when present are of consequence only when very low resistance units are being checked. High resistances measurements are not effected by the variation of the meter resistance.

When high resistance circuits are to be tested the DPDT switch is thrown to the position where R1 is shunted across the meter terminals. The test prods are shorted and R1 is adjusted so that the meter reads full scale. When the DPDT switch is thrown in the opposite position, the shunt is removed and the meter will read

approximately full scale. The variable resistor R2 then is adjusted so that the meter reads exactly full scale, 1 milliamperes.

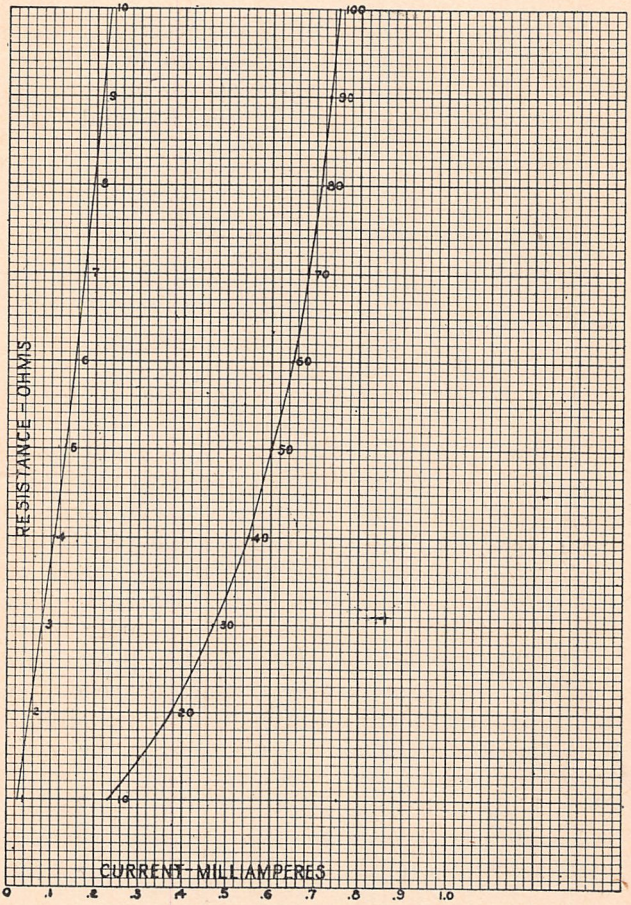


Fig. 53
Calibration curve for resistance values between 1 and 100 Ohms

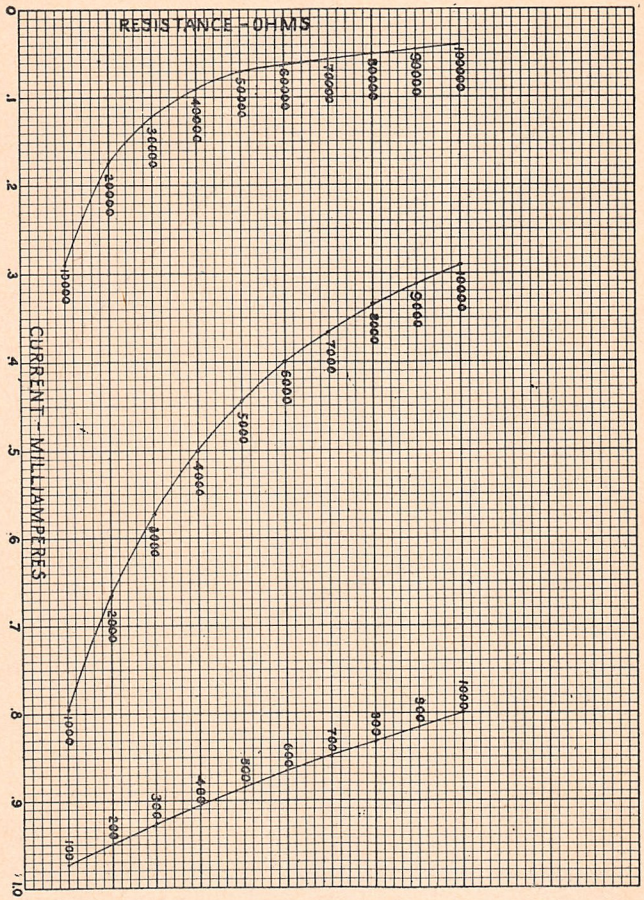


Fig. 54
Calibration curve for resistance values between 100 and 100,000 ohms

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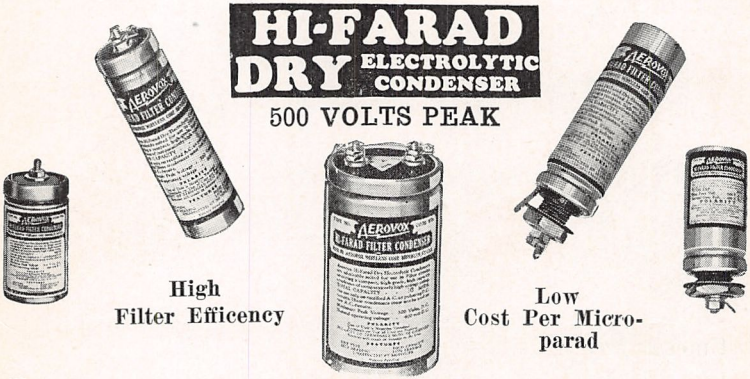

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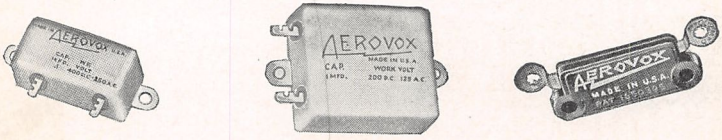

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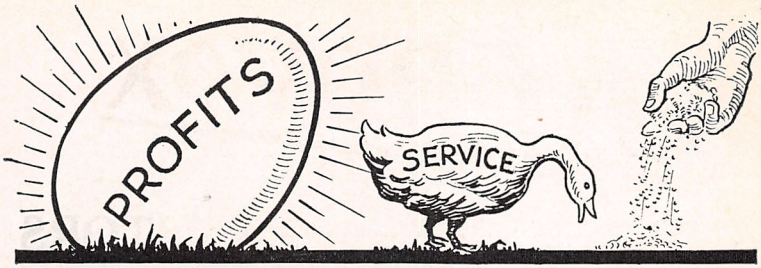

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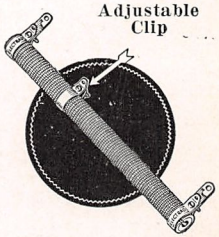

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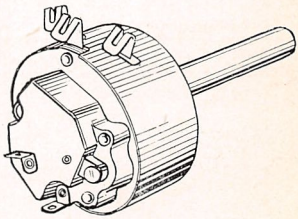

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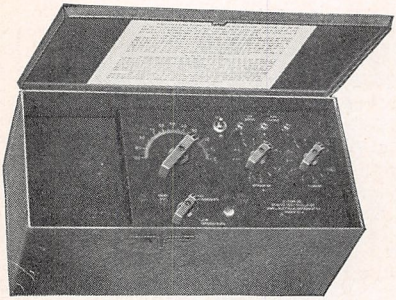

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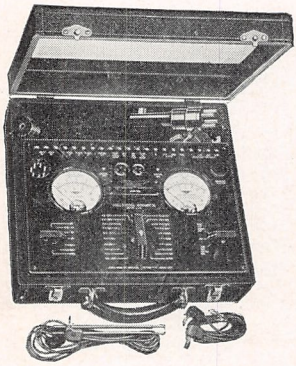

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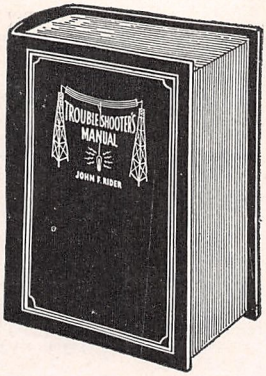

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